

# M28 FIXED WING TRANSPORT AIRCRAFT COST REDUCTION

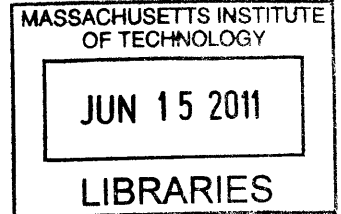
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Submitted to the MIT Sloan School of Management and the Engineering Systems Division in  
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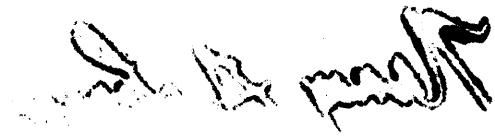
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# M28 Fixed Wing Transport Aircraft Cost Reduction

By Yuxin Xia

Submitted to the MIT Sloan School of Management and the Engineering Systems Division on May 8, 2011 in partial fulfillment of the requirements for the degrees of  
Master of Business Administration and  
Master of Science in Engineering Systems

## Abstract

The M28 is a Polish short-takeoff-and-landing (STOL) light cargo aircraft developed in 1984 and currently built by PZL Mielec, a subsidiary of United Technology Corporation (UTC). There has been renewed interest in the product from military and commercial markets due to its impressive STOL capabilities. However, in order to become price-competitive, its cost would need to be reduced significantly.

Multiple cost-reduction concepts have been proposed by the manufacturing and procurement groups. An Optimization Team was also formed to lead the cost-reduction effort. However, a more systematic approach is required in order to achieve the ambitious reduction goals. The proposed solution is to create a top-down systematic cost-reduction framework used to coordinate and prioritize the team's current bottom-up approach.

A top-down cost reduction strategy was developed based on UTC Otis' *Octopus Fishing* concept. Such methodology, heavily finance driven, systematically breaks M28 into sub-systems, and prioritizes improvement recommendations based on cost-reduction potentials. It also leverages on the wealth of knowledge from global cross-functional teams to generate explosive amount of improvement recommendations. The sub-systems were benchmarked against competitors cost structures. The framework will be linked to concepts generated from the database to create a process that combine top-down and bottom-up approaches.

After tasks were prioritized using the outlined framework, a three-prong approach was implemented to enhance cost reduction capability. Manufacturing of labor intensive parts such as nacelle deflection cover was automated using CNC machines. A set of commodity purchasing strategies were formulated for forgings, avionics, raw materials, interior and composite materials. Lastly, a discrete Kaizen event was described to aid redesign-for-manufacturing.

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## **Chapter 1. INTRODUCTION**

The goal of this thesis is the cost reduction of PZL's M28 aircraft in response to increasing market pressure. As background, overviews of Sikorsky Aircraft Corporation, the parent company, and PZL Mielec, the subsidiary will be presented. The history of Poland that led to the acquisition of PZL will be briefly discussed. The subsequent market conditions, including the states of competitors will be presented to justify the need for cost reduction. To build up the cost reduction tool box, Sikorsky's current practices for subsidiary integrations will also be discussed.

### **1.1 Company Overview**

#### **1.1.1 Sikorsky Aircraft Corporation**

Sikorsky Aircraft Corporation is a leading American helicopter manufacturer well known for its high performance military models, such as the UH-60 BLACK HAWK and the SH-60 SEA HAWK. The company was founded in 1925 by Igor Sikorsky, a Kiev-born American immigrant and a pioneer of aviation in both helicopters and fixed wing aircraft. In 1929, the company headquarters relocated from Roosevelt, New York to Stratford, Connecticut, and became a part of United Aircraft and Transport Corporation, now United Technologies Corporation, in July of the same year. Since then, the company has remained at the cutting-edge of helicopter development. Its X2 technology helicopter is capable of exceeding 225 knots, beating the current FAI rotorcraft world speed record of 216 knots set by a modified Westland Lynx in 1986(Sikorsky Aircraft Corporation). Domestically, Sikorsky's main plants are located in

Stratford, Shelton, Bridgeport Connecticut, Fort Worth, Texas, West Palm Beach, Florida, and Troy, Alabama.

At the same time, its global presence has expanded significantly in response to the rising global demand for helicopters. Additional facilities have been built overseas for strategic and operational reasons. However, the rapid expansion creates integration complexities for its global operations organization.

### **1.1.2 PZL Mielec**

PZL Mielec (*Polskie Zakłady Lotnicze*), is currently the largest manufacturer of fixed wing aircraft in Poland. It has rich 70-years of aviation manufacturing history and produced over 16,000 aircrafts.

In 1928, PZL (*Państwowe Zakłady Lotnicze*), or Polish Aviation Factory, was founded in Warsaw as a state-owned company (Glass). It subsequently built a number of factories: its main factory, PZL WP-1 was built in Warsaw in 1934; PZL WP-2 was built in Mielec in 1938; a British Bristol engines factory, PZL WS-1 was built in Warsaw-Okęcie; another engine factory, WS-2 was built in Rzeszów in 1937. PZL WP-2, the predecessor of PZL Mielec, was built in Mielec in 1938.

During World War II, the Polish aviation industry was completely destroyed. PZL WP-2 factory in Mielec became a part of Heinkel during the German occupation. After the war, the PZL brand disappeared, as the communist government broke ties with pre-war Poland. PZL was renamed WSK, or Communication Equipment Factory (*Wytwórnia Sprzętu Komunikacyjnego*). WSK-Mielec became the biggest post-war Polish aircraft producer, mainly manufactured

licensed Soviet planes. Its list of aircrafts included the Antonov An-2 transport biplane, the MiG-15 and MiG-17 jet fighters. It also manufactured Polish-designed TS-11 Iskra jet trainer, TS-8 Bies piston trainer, and the world's only jet agricultural plane, the PZL M-15 Belphegor. Large numbers of planes were exported to the USSR.

The PZL brand returned at the end of the Stalinist period in 1956. PZL Aircraft and Engine Industry Union (*Zjednoczenie Przemysłu Lotniczego i Silnikowego PZL*) was formed in 1973, grouping all state-owned aerospace industry factories in Poland (Babiejczuk and Grzegorzewski). It consisted of 19 factories, a research institute, and the Pezetel Foreign Trade Center, including all Polish industries aboard. During this period, WSK PZL-Mielec produced mostly its self-developed civil aircrafts. The most notable are the M18 Dromader agricultural plane, and the M28 Skytruck and Bryza light transport planes.

The union dissolved in 1989 after the fall of communism in Poland. Its members, including WSK PZL-Mielec, became separate plants but retained the PZL name. Many sister plants, such as PZL Warszawa Okęcie (formerly known as PZL WS-1) and WSK PZL-Kalisz, remain major suppliers for M18 and M28.

During the beginning of twenty first century, Sikorsky was seeking to acquire M&A targets. The goals of M&A are three folds:

- **Increase production capacity.** The existing BLACK HAWK assembly sites will be reaching full capacity, and a new factory will be needed for growth
- **Offset requirements.** In the aviation industry that relies heavily on public government's financial support, manufacturing companies usually need to offer benefits (e.g. job creation) to a targeted market in return for order contracts. Political obstacles are also

lowered for products that are partially produced at the home country. Since Europe is one of the largest markets outside of US, it is the ideal location for capacity expansion

- **Seek NATO partners.** Due to technology export concerns, Sikorsky can only produce BLACK HAWK at NATO countries. Consequently, other potential candidates such as Middle East or Southeastern Asia, cannot be targeted despite its large market potential and low labor cost

In October 1998, WSK PZL-Mielec went bankrupt, and was converted into state-owned company *Polskie Zakłady Lotnicze Sp. z o.o.* The company fits all of Sikorsky's acquisition requirements. Being a brownfield factory, it provided a skilled labor force with in-depth manufacturing expertise. In fact, the goal of the acquisition was not to reduce labor cost, since labor rate between Eastern Europe and US are approximately the same. On March 16<sup>th</sup>, 2007, PZL Mielec was acquired by Sikorsky Aircraft Corporation. The PZL and PZL Mielec names will be used interchangeably in the following discussions.

While retaining its M18 and M28 product lines, PZL became the final assembly site for the international version S-70i BLACK HAWK helicopter. With heavy capital investment, the communist-era facility was completely renovated. Comprehensive upgrades have been made throughout the facility, including Information Technology (IT) network, equipment updates, and installations of new manufacturing equipments such as best-in-class CNCs. It also installed modern security systems and implemented Environmental Health and Safety (EH&S) units. After the transformation into a state-of-the-art facility, PZL attracts international visitors daily, including high-level government officials as well as the LGO group from MIT in 2009 as part of its International Plant Trek.

Its Soviet heritage has directly affected PZL's manufacturing models. Under communism, heavy industrial manufacturers were stand-alone entities. They did not import or export manufacturing parts, and the concepts of supplier relationships and outsourcing were non-existent. Large manufacturing entities, such as PZL Mielec, manufactured virtually every component required to build and support its aircrafts. It manufactured seats and seat belts. It manufactured airplane covers and service elevators used for aircraft maintenance. It manufactured emergency exit axes and toolboxes. It also manufactured its own screws, rivets and fasteners. Without the economies of scale needed to spread manufacturing costs, some of its highly specialized screws could cost up to few hundred dollars each. In essence, PZL Mielec is a fabric, furniture, luggage and hardware producer as well as aircraft manufacturer.

After Sikorsky's acquisition in 2007, upper management had tried hard to reduce cost by selling off non-core assets and initiated make-to-buy procurement decisions. Unfortunately, the transition had been slow. First, legacy aircrafts, such as M18 and M28, have been designed with the assumption of producing components in-house. Consequently, many of its parts are highly specialized, and could not be purchased off-the-shelf from suppliers. In order to switch from make to buy, radical redesigns are required. Second, many of the local suppliers do not have the expertise of supporting aerospace industry. Under communism, while the large manufacturers were capable of producing virtually every component, the small counterparts had poor production capabilities. Consequently, PZL needed to actively build up suppliers' production capabilities before initiating outsourcing.



## **1.2 Sikorsky current practices for subsidiary integration**

PZL Mielec is one of many international acquisitions undertaken by Sikorsky within the past twenty years. As Sikorsky grows, its operations team not only has to satisfy the increasingly complex organizational requirements, but also retain the agilities needed to solve subsidiary-specific challenges. In addition to site-specific post-acquisition activities, Sikorsky corporate has developed additional programs that help to streamline operations among different manufacturing facilities, and ensuring uniformity in product qualities. Two programs, the UTC Supplier Gold and UTC Operations Work Transition Management Policy were developed to set standards for the subsidiaries' supply chain organizations.

### **1.2.1 UTC Supplier Gold Program**

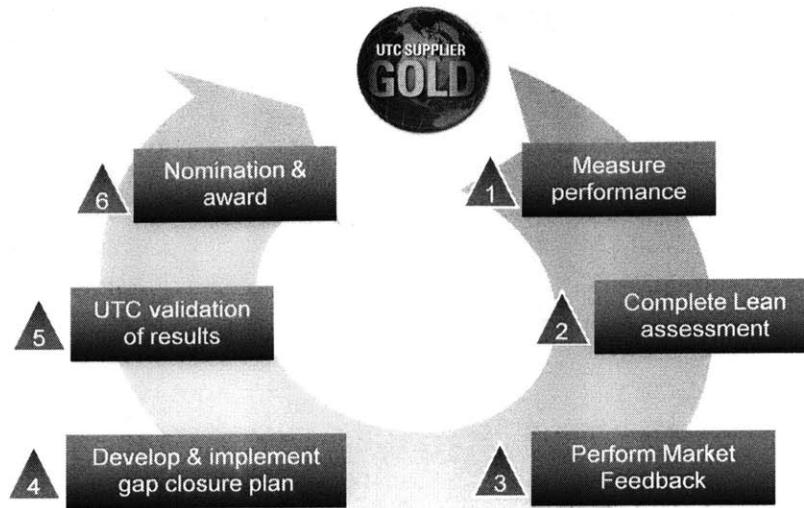
In 2007, over 75% of UTC product components were bought compared to 68% from 2001. UTC Supplier Gold is a corporate-wide supplier performance evaluation program which resulted from the company's increasing dependency on supplier. This program has now been instituted in all Sikorsky companies. The goal is to evaluate supplier performances, recognize excellence and provide improvement recommendations. Suppliers are evaluated based on four criteria: Quality, customer defined delivery, UTC lean assessment, customer satisfaction. They are grouped into four levels: underperforming, progressing, performing and gold. The highest gold standard requires:

- Quality: Zero escapes sustained over a 12 months period
- Customer defined delivery: Satisfying requirement 100% for the last 12 months period

- UTC lean assessment: A score greater than or equal to 350 for Manufacturing and 260 for Services or Distributors
- Customer satisfaction: Average score equal to 6.0 or better on a 7 point scale

The suppliers under the program are evaluated by a six-part process (Figure 1). Each supplier has a UTC Scorecard that tracks performance based on the four criteria. The lean evaluation is an on-line self assessment survey completed by supplier. The survey measures performance based on the dimensions of strategic planning, customer satisfaction, teamwork, production, quality and safety. A market feedback analysis, or MFA survey, is completed by all UTC buying organizations of a given supplier. The survey asked buyers to rank their experience on a scale of 7, in categories of cost competitiveness, quality, delivery, ease of doing business, customer support, responsiveness and flexibility.

Using UTC Scorecard, lean assessment and market feedback, performance gaps are first identified. Gap closure plans are identified using improvement techniques such as TPM, 3P, or QCPC. UTC then validates assessment result and correction plan, including a facility walkthrough and additional lean assessment of supplier. At the last of the six step process, a supplier is nominated to UTC for Supplier Gold. Suppliers that achieved gold status received UTC leadership visibility, and distinguish themselves among their peers.



**Figure 1: UTC Supplier Gold Program**

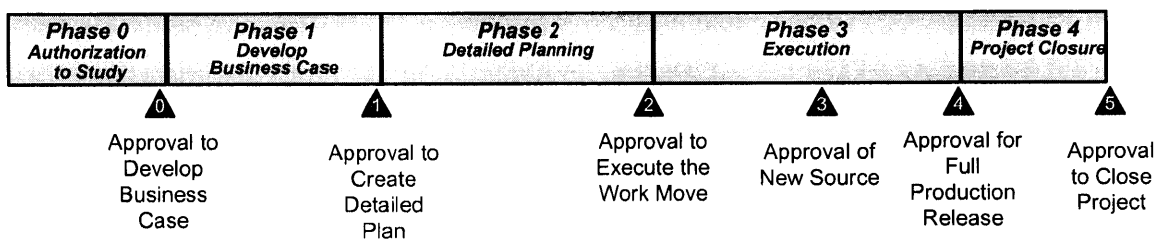
When the program was first instituted at PZL, the majority of suppliers were graded at the under-performing level. Since then, PZL has invested heavily to improve supplier performances. It recruited a dedicated Supplier Gold staff, and began UTC ACE training for staff members. It implemented MFA and lean tools at supplier location, and established standard work.

### **1.2.2 UTC Operations Work Transition Management Policy**

A large percentage of projects at PZL as well as other subsidiaries are classified as “transition projects.” They are either transition from make to buy, buy to make, or are resourcing projects (i.e. transition from make to make and buy to buy).

UTC Operations Work Transition Management Policy is a gated process used to ensure successful work transitions within each of UTC’s subsidiaries. It provides uniform and clear definitions of minimum requirements necessary to ensure effective work transitions.

According to the policy, the transition process consists of five phrases and six gates of approvals (Figure 2 and Figure 3). The process starts with a clear definition of business case that emphasizes financial impact. It is used to confirm the alignment of the work transition with high-level organization’s strategy and financial goals. Such step is critical in developing finance-oriented thinking not only at the mid-management level, but also at the project execution level. At each approval gate, a Passport Review Board (PRB) consists of key stakeholders reviews project progress. The board is critical in ensuring accountability. The level of PRB oversight varies depending on the degree of assessed risk, project duration, number of participating division, supplier type and financial value associated with proposed work transition. For example, a level 1 project consists of program value of \$0.25m to \$0.5m only requires PRB with program managers. On the other hand, a level 5 project consists of program value of greater than \$10m requires the approval of subsidiary president. Upon the project is reviewed, it is either approved for continuation (“Go”), required to acquire additional information (“Redirect”), or cancelled (“No-Go”).



**Figure 2: Five phrases of UTC work transition gated process**

## P0 - Approval to Develop Detailed Business Case

**Objective:** Approve the initial Statement of Work and preliminary business case, and identify req'ts for Phase 1.

**Decision to be made:** Are we ready to approve project for detailed business case development?

## P1 - Approval to Create Detailed Plan

**Objective:** Identify and review all aspects of the business case, identify recommended supplier, identify resourcing requirements/schedule, quality requirements and finalize the project statement of work.

**Decision to be made:** Are we ready to launch the project and commit resources (including expenditures for labor, material, and capital equipment)?

## P2 - Approval to Execute the Work Move

**Objective:** Verify all transition plans including detailed manufacturing schedule, risk mitigation plans, and new source qualification plans.

**Decision to be made:** Are we prepared to execute this transition and release the supplier contract?

## P3 - Approval of New Source

**Objective:** Verify integrity of initial production and readiness to deliver product to schedule needs

**Decision to be made:** Are we ready to accept production parts from the new source?

## P4 - Approval for Full Production Release

**Objective:** Verify transition completion in accordance with all project requirements.

**Decision to be made:** Are we ready to shut off the original source?

## P5 - Approval to Close Project

**Objective:** Verify transition completion in accordance with all project requirements, identify lessons learned and MFA relative to Transition Standard Work, and identify any future plans for supplier.

**Decision to be made:** Are we ready to formally close out this project?

**Figure 3: Five phrases of UTC work transition gated process description**

### 1.3 M28 product overview

As Poland joins the European Union, transitioning from a socialist to an open market competitive economy, PZL will need to manufacture aircrafts that directly respond to the market requirements. In fact, the cost reduction of M28 aircraft, the focus of this thesis is a direct consequence of the rapidly changing market conditions. The following discussion is included to provide sufficient understanding of the M28 market. The global aviation market will first be presented, followed by a detailed discussion of M28's turboprop market. M28's

competitors will also be presented. Their manufacturing processes are critical for benchmarking at a later part of this thesis.

### **1.3.1 Aviation market overview**

The global aviation market consists of the civil and military aircraft markets. The key driver for the civil market is economic growth. Despite the recent period of worldwide recession, the world economy is projected to grow at a rate of 3.2% per year over the coming 20 years, compared with 2.8% in the past 20 years (Japan Aircraft Development Corporation). Consequently, world airlines will achieve an average growth of 4.9% per year, with the traffic volume in 2019 reaching 2.6 times the level in 1999. As demand for air transportation increases, the number of aircrafts required will increase substantially as well.

The commercial market could be further divided into mainline, regional, and general aviation markets (Frost and Sullivan). The mainline market (Figure 4), consisted of large passenger aircrafts and jumbo jets, is dominated by Airbus and Boeing. A machinist strike at Boeing, in addition to the repeated production delays of the new Boeing 747-8 and 787 aircrafts have resulted in significant drops in delivery from 2008 to 2010. Furthermore, persistent high fuel prices and global recessions have caused multiple order cancellations and deferrals. However, as economy recovers and production of new aircraft matures and stabilizes, the mainline aircraft delivery is expected to reach above 900 by 2013.

The regional aviation market (Figure 5) consists of commuter aircraft, characterized by shorter flight distances and lower seat counts. It is sometimes characterized by route distance of under 1000 km (Japan Aircraft Development Corporation), or with maximum seating between

30 and 75(Wendell H. Ford Aviation Investment and Reform Act for the 21st Century). The main market players are Embraer that hold 50% of market share, Bombardier (34%) and ATR (17%). This segment has faced similar market pressure as the mainline segment. Furthermore, ridership has remained low, and cost of aircraft operations, such as fuel cost, remains high. Consequently, order cancellations and deferrals are expected to accelerate in the upcoming years. In response, Embraer announced major cut-backs in production of regionals in 2009. Consequently, regional aircraft delivery is expected to stabilize around 175 by 2013.

General aviation (GA) market (Figure 6) consists of small size utility aircrafts such as crop duster, skydiving, firefighting and exploration aircrafts. GA is often defined as all flights other than military and scheduled airline flights, both private and commercial. There are eight main market players, with Cessna holding 35% market share. In 2008, general aviation deliveries faced the first downturn in five years, and the trend has continued to 2010. This segment faced a number of high profile corporate cancellations, as a result of the automotive CEO appearances before Congress, and government financing to public companies. The unavailability of financing and production position swaps was main cause for order deferrals.

Turboprop engine aircrafts competes with jet and piston engine aircrafts in the regional and general aviation segments. Piston aircraft, while being the dominant player in the general aviation market, has faced drastic order cancellations in the recent years. Jet aircraft, in extension from its mainline market, has fierce competition with turboprop aircraft in the regional market segment. It provides better passenger appeal, with faster and smoother flight experience. It also has better marketing image, since turboprop is generally considered

outdated technology. However, regional jet fleet has prohibitive capital investment cost. An average regional jet costs \$25 million USD, while a turboprop aircraft costs as low as \$7 million USD.

Turboprop aircraft holds additional advantages over its competitors other than production cost. It costs less to operate. Regional jets are generally larger, requiring more flight crews and resulting in higher fuel and maintenance costs. The current route fare structure is extremely difficult in supporting the high cost of jets. Turboprop aircraft also has superior short take-off and landing (STOL) capabilities.

There is no single definition for STOL. Some of the commonly accepted definitions include:

"The ability of an aircraft to clear a 50-foot (15 meters) obstacle within 1,500 feet (450 meters) of commencing takeoff or in landing, to stop within 1,500 feet (450 meters) after passing over a 50-foot (15 meters) obstacle."(United States Department of Defense)

"A STOL aircraft is an aircraft with a certified performance capability to execute approaches along a glideslope of 6 degrees or steeper and to execute missed approaches at a climb gradient sufficient to clear a 15:1 missed approach surface at sea level... A STOL runway is one which is specifically designated and marked for STOL aircraft operations, and designed and maintained to specified standards."(US House of Representatives Committee of Science and Technology)



Such characteristic is critical for regional airlines operating with short runways. With more suitable operating environments, turboprop aircraft could achieve higher utilization rate than regional jets.

There has been rapid progress in turboprop engine development as well. In general, turboprops are very efficient at modest flight speeds below 450 mph, because low jet velocity of the propeller. (Turboprop) Pratt & Whitney Canada Corp, with its venerable PT6 model, has been the dominate player in the turboprop engine market. To maintain its position, it has been heavily investing in technology that reduces engine noise and improves flight comfort level.

Increase in public environmental awareness also helps to generate demand for turboprop planes. Regulatory initiatives, such as the Kyoto Accords, have placed strict carbon-emission restrictions around the world. While aviation industry was exempted from Kyoto Accords guideline, it delegated the responsibilities to the International Civil Aviation Organization (ICAO). In response, ICAO has established a goal of 2% annual improvement in fleet fuel efficiency. The European Union (EU), being in the forefront of environmental regulations, has placed additional “green” penalty tax and emission cap-and-trade initiatives. As a result of high fuel cost and “green” awareness, airlines are reducing the number of flights and using more regional carriers. As carriers shift from mainline to regional, the turboprop market will increase.

Consequently, turboprop aircraft has become a dominant player in the commercial market. In 2008, a third of total regional aircraft production was turboprop deliveries. (Frost and Sullivan) Despite the abysmal regional market condition in 2008, Bombardier and ATR had

modest increases in turboprop production. Turboprop has also been less affected by the economic downturn in 2008.

Turboprop aircraft, leveraging on its superior STOL capability, also generates significant interest in the military market. The recent war in Iraq and Afghanistan has resulted in a high demand for aircrafts capable of operating in limited airfields. It also requires transport capability from aircraft carrier with short runways. On the other hand, emerging nations have increased investments into air forces. Vietnam, for example, has its military bases situated on islands with short run-ways. In multiple scenarios such as this, turboprop plane provides the most cost-effective solution.

In summary, market analysis shows PZL's M28 aircraft's high profitability potential in commercial and military markets.

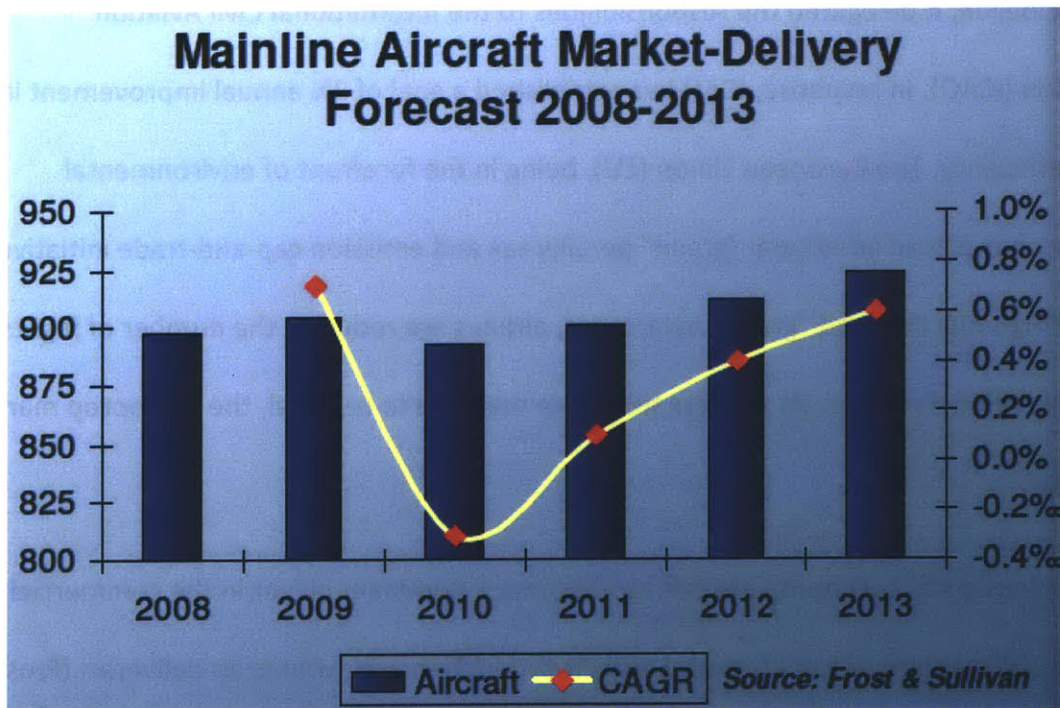


Figure 4: Mainline Aircraft Market-Delivery Forecast 2008-2013

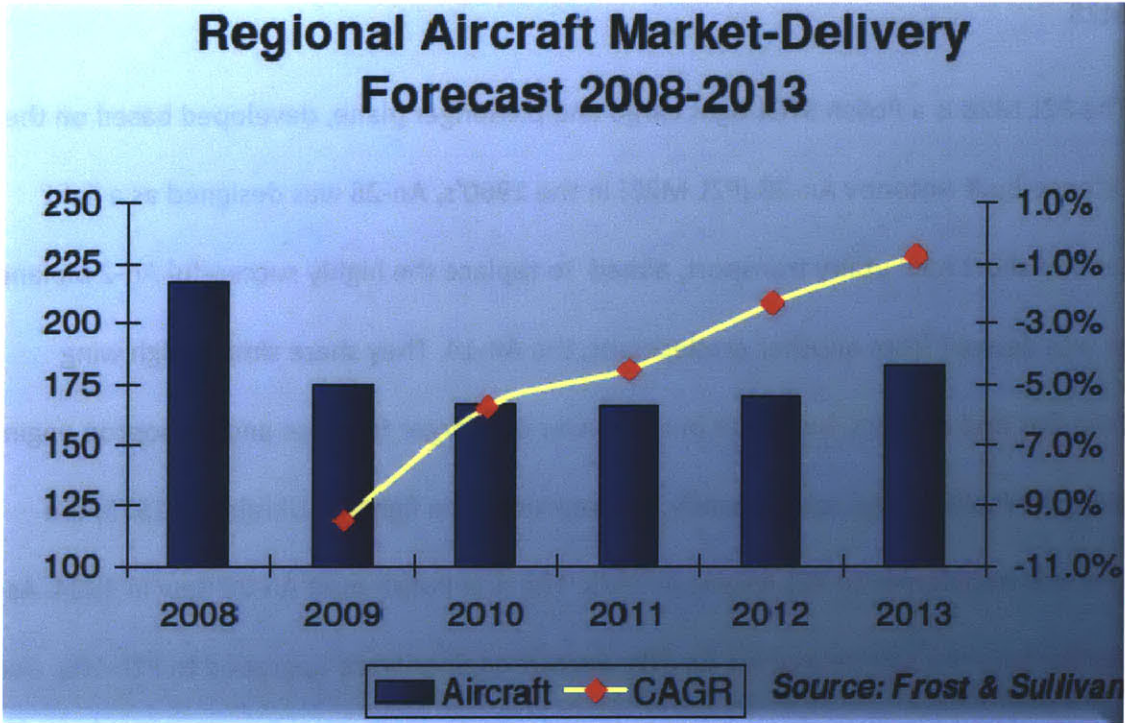


Figure 5: Regional Aircraft Market-Delivery Forecast 2008-2013

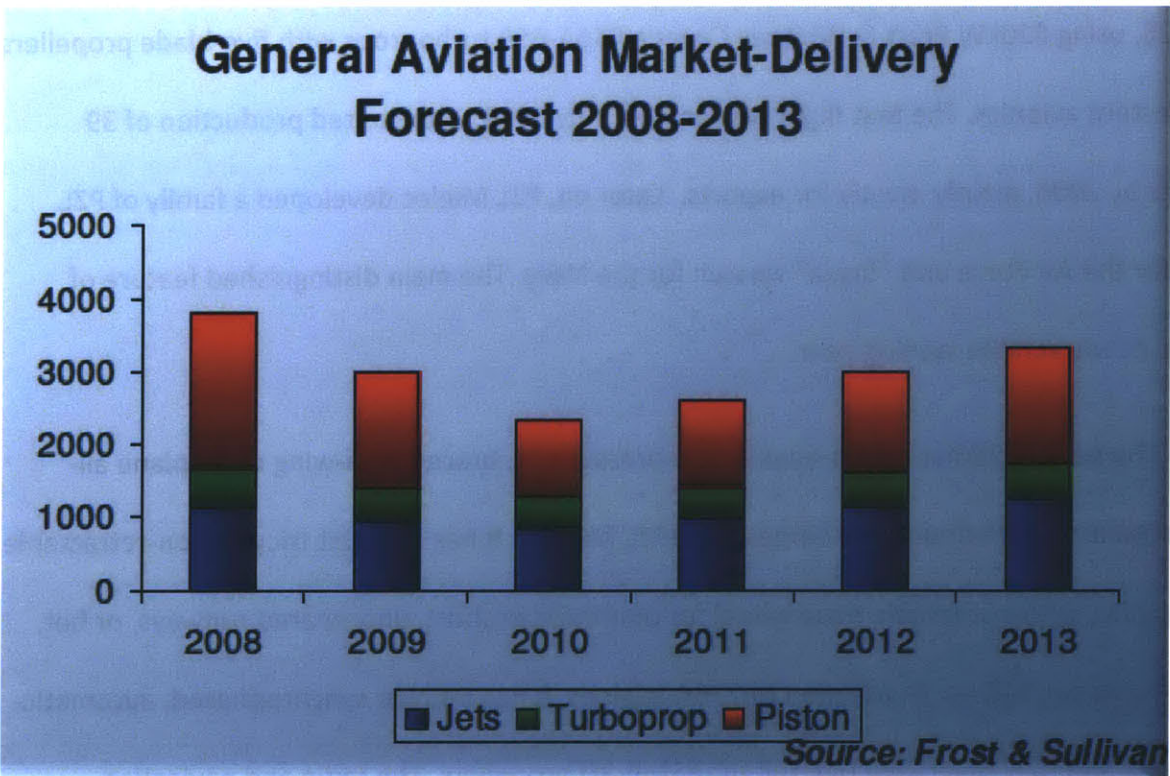


Figure 6: General Aviation Market-Delivery Forecast 2008-2013

### 1.3.2 M28

The PZL M28 is a Polish STOL light cargo and passenger plane, developed based on the historic license-built Antonov An-28.(PZL M28) In the 1960's, An-28 was designed as a light passenger and short haul utility transport, aimed to replace the highly successful An-2 biplane. Its design was derived from another predecessor, the An-14. They share similar high wing layout, twin fins and rudders, but differ in the newer and larger fuselage and turboprop engines. After making its maiden, and subsequently, its preproduction flights in Ukraine in 1975, the production was transferred to PZL Mielec in 1978. The first Polish-built An-28 flew in 1984. As PZL Mielec became the sole source for An-28s, aircraft engines were upgraded to PZL-10S, also known as TWD-10B engines.

In the late 1980's, PZL has decided to develop a westernized version of An-28, named PZL M28, using 820kW Pratt & Whitney Canada PT6A-65B turboprops with five-blade propellers, plus western avionics. The first flight was on 24<sup>th</sup>, July 1993, with limited production of 39 aircrafts by 2006, mainly mostly for exports. Later on, PZL Mielec developed a family of PZL M28B for the Air Force and "Bryza" version for the Navy. The main distinguished feature of Bryza is its retractable landing gear.

The basic M28 has a twin-engine non-pressurized, braced high-wing monoplane all-metal structure, with double fin empennage(PZL Mielec). It has a robust tricycle non-retractable landing gear, with a steerable nose wheel for operation in short, unprepared runways, or hot, high altitude conditions. In addition to PT6A engines, it has 5-blade synchrophased, automatic-feathering and fully reversible Hartzell HC-B5MP-3D propellers. The radio and navigation

equipments (B/K Gold Crown Series) are installed to service VFR and IFR day and night operation. The pressure refueling connection on rear fuselage port is designed to facilitate servicing. Besides the pilot entry door, the airplane is equipped with a rear cargo door, an option unavailable from most of its competitors. This additional feature is provided in three configuration options: clamshell, with doors that are hydraulically openable on ground and in flight; a single-leaf type mechanically openable on ground; a ramp door for passenger entry and cargo loading.

M28 is operated by a crew of 2 pilots. It offers the highest total payload in its class – up to 2300 kg. In addition, it could be fitted with underfuselage cargo pod, carrying 300 kg load. Alternatively, the airplane can carry up to 19 passengers or 17 paratroopers. It is also available in special mission configurations.

To summarize, M28 capabilities include:

- High-wing arrangement for engine and propeller protection against damage when operating from unpaved airstrips
- Easy access rear cargo door
- Easy and quick conversion of cabin interior configuration to suit different mission requirements
- PT6 engines proprietary design that prevents Foreign Object Damage (FOD)
- Turboprop engines provide perfect flight handing at low airspeeds
- Highest useful load of its class

- Shortest STOL capability in its class, with takeoff distance of 325m and landing distance of 490m
- Unpaved airstrip and high-elevation operating capability

In contrast to its competitors, M28 has a relatively short operational history. 176 An-28 and M28 were built in Poland by 2006. Most were used in former Soviet civil aviation and the Polish Air Force and Navy. Less was used by the Polish civil aviation. In recent years, there has been increasing interest by the US military on M28. Its exceptional STOL capability enables them to perform in hazardous battlefield environment in Iraq and Afghanistan as well as operator from aircraft carriers. An additional benefit is, since it is originally a Soviet design, the M28 appears less conspicuous in hostile environments that target US military aircrafts.

Comparisons among competitors, including the Beechcraft 1900 and Super King Air, CASA C-212 Aviocar and Cessna 208 Caravan are shown in Figure 7. Twin turboprop STOL market, M28's targeted market, has a projected ten year market size of \$2.5B. Its current dominant player is the DHC-6 Twin Otter, holding 45% market share. STOL data shows that Twin Otter has the best performances, comparable to M28. While the two Beechcraft models are M28's competitors in the greater regional market, they do not have the capability needed to compete in STOL market. Furthermore, Beechcraft 1900 production has been terminated. Cessna Caravan is also not considered in this study since it uses single turboprop engine. In reality, aviation safety data has showed little statistical differences between single and twin engine performances.(Sefofane) Furthermore, FAA has allowed single-engine aircraft to be used in commercial sector since 1997.

Discounting planes manufactured by Beechcraft and Cessna, the remaining major competitors will be presented in detail in the Appendix A.

Name	Manufacturer	Current Fleet	First flight	Number built	Power Plant	Power Plant Rating	Takeoff	Landing	STOL	Payload
PZL M28	PZL Mielec	176	1993	176	2x P&W PT6A-65B turboprop	820kW	325m	490m	X	6782lb
Dornier Do 228	Dornier GmbH (Germany)	270	1982	270	2x Garrett AiResearch TPE-331-5-252D turboprop	578kW	620m	500m	X	5158lb
Dornier 228 New Generation	RUAG (Swiss)		2010	4	2x Garrett AiResearch TPE-331-10 turboprop	533kW	793m	793m	X	6400lb
DHC-6 Twin Otter	de Havilland Canada/ now Viking Air of Victoria (British Columbia)	845	1965	845	2x P&W PT6A-27 turboprop/2x P&W PT6A-34 (400 Series)	460kW-507kW/560 kW	366m	366m	X	4500lb
Beechcraft 1900	Beechcraft of Raytheon (now Hawker)	695	1982	695	2x P&W PT6A-65B turboprop	955kW	1600m	1600m		4000 lb
Beechcraft Super King Air	Beechcraft of Raytheon (now Hawker)	3550+	1974	3550	2x P&W PT6A-52 turboprop	635kW	1200m	1200m		2220lb
CASA C-212 Aviocar	EADS CASA (Spain), IPTN (Indonesia)	478	1971	578	2x Garrett AiResearch TPE-331-10R-513C turboprop	690kW	895m	865m	X	17600lb
Cessna 208 Caravan	Cessna	1500+	1982	15000	1x PT6A-114 turboprop	505kW	680m	650m	X	8750lb

**Figure 7: M28 and competitors specifications comparison**

#### 1.4 Problem statement and thesis structure

As illustrated by the comparison Figure 7, M28 has the best performance capabilities among the competitors in the turboprop STOL aircraft market. Unfortunately, the aircraft is priced at 28% above its competitors. A cross-functional Optimization Team has been formed, with the goal of reducing product cost by 28%. The goal of the project is to provide a set of

labor and material cost reduction recommendations. Since both manufacturing and procurement organizations are key drivers for the aircraft cost, cost reduction strategies will be devised for both organizations.

The structure of this thesis consists of three components. Chapter 2 and 3 summarize the industry knowledge applicable to this project. Chapter 2, the literature review section, reviews the best-in-class cost tracking and reduction techniques. In order to execute cost reduction plan effectively, the change agent will need to understand the change techniques used for complex organizations. A number of organizational change concepts will be presented here. Chapter 3 will present two best practice examples: UTC Otis on cost tracking techniques, and ABB on organizational change when entering Eastern European market.

After an industry review, a two-part cost reduction process is presented. The first part is a resource allocation approach. It analyzes M28 cost structure and allocates resources to cost reduction sub-projects based on financial value. Chapter 4 presents M28 and competitor's cost structure as well as a detail resource allocation approach.

The second part is a three-prong approach to cost reduction based on manufacturing, procurement and design. Chapter 5 presents labor cost reduction through automation in the manufacturing organization. Chapter 6 presents material cost reduction through the implementations of commodity purchasing strategies. Chapter 7 presents an Octopus Fishing Kaizen event stemmed from UTC Otis cost reduction technique aimed to reduce cost through redesign for manufacturing.



## 1.5 Summary of recommendations from the three-prong approach

As described in the last section, a three-prong approach to cost reduction will be described later in the thesis. The three sets of recommendations are summarized here.

Specifically, labor cost reduction through automation requires:

- Raising M28 product awareness throughout UTC organization
- Dedicating a champion that drives automation effort
- Developing long term transition plan from craft production to automated manufacturing

Material cost reduction are accomplished through commodity purchasing strategies. Forging and casting strategies are:

- Developing second source to reduce Russian materials supply risk
- Directly purchasing from manufacturers
- Leveraging on Sikorsky's buying power to renegotiate price
- Developing Long Term Agreement with suppliers
- Developing bundling LTA with other Sikorsky subsidiaries
- Consolidating supply base

Fasteners strategies are:

- Single-point sourcing for fasteners
- Reducing supply chain complexity by consolidating and minimizing the number of fasteners type
- Modernizing sourcing operations using just-in-time principles

- Outsourcing remaining fasteners manufacturing operation
- Improving fasteners material quality

Avionics and electronics strategies are:

- Directly purchasing from manufacturers
- Redesign using non-Soviet avionics
- Transitioning from P.O. to LTA
- Developing bundling LTA with other Sikorsky subsidiaries
- Consolidating supply base

Lastly, to promote re-design for manufacturing, biannual Kaizen event using UTC global resources is recommended.

## **Chapter 2. LITERATURE REVIEW**

### **2.1 State-of-the-art cost tracking and reduction techniques review**

In the past decades, increasing globalization and wide adaptations of lean manufacturing practices, have forced companies to continuously improve its cost structure in order to remain competitive. Such trend, once limited to consumable sectors, has expanded to the aerospace and defense industries. The mainline aircraft manufacturers, such as Boeing and Airbus, are competing on product performance such as fuel efficiencies that are directly linked to end-customers' operation and maintenance costs. While government subsidies have helped to alleviate pressure in the military aviation market, cost became a dominant competitive advantage as defense budgets become limited. As presented in the previous chapter, multiple turboprop manufacturers exist in the military and commercial regional markets, producing STOL aircraft with similar performances. In order for PZL Mielec to succeed in such environment, it must develop competitive cost advantage. A review of state-of-the-art costing methods will be presented here.

In order to develop an effective cost-reduction technique, an accurate model of the current cost structure must be formulated first. Different cost estimation techniques exist, each with its own specific characteristics, advantages and disadvantages.(Curran, Raghunathan and Price) These techniques could be categorized into five groups: analogous cost estimation, parametric cost estimation (PE), activity based costing (ABC), bottom-up cost estimation, and top-down cost estimation.

According to analogous cost estimation and Case Based Reasoning (CBR), product cost is projected based on historical like-products. The technical similarities between products are used to estimate the current product cost. At the same time, the differences are used to refine and adjust the cost structure, in order to account for variations in factors such as product complexities, technical and supply chain discrepancies. Modern forms of analogous-type costing takes advantage of neural network theory, to create computer models that predict the cost structure given certain product attributes. Unfortunately, such technique requires a large population size that is split into input and test groups. In general, analogous cost approach is highly sensitive to change in design, material selection and process requirements. These approaches also demands large quantity of historical data for benchmarking. For new product introduction with radical different product parameters, such information is often unavailable. To benchmark against competitors, intense market research or product reverse-engineering is required.

Under parametric cost estimation, cost of a product is linked to technical parameters such as weight, size or component count. To link cost to the technical parameters, Cost Estimation Relationships (CERs) are developed based on historical data using statistical techniques. Many commercial PE software and hardware, such as COCOMO II, PRICE-H, SEER-SEM, SSCM and USCM8 have been developed.(Valerdi, The constructive systems engineering cost model (COSYSMO), 2005 Ph.D. dissertation) Building on previous learning in the field of PE, Constructive System Engineering Cost Model (COSYSMO) was developed by Dr. Ricardo Valerdi in 2005. Data was collected from six aerospace companies in the form of expert opinion and

historical project data to define and calibrate the model. Sixteen size and cost drivers and their ranges were determined.

It is generally accepted that PE model is extremely useful during the early stage of product development. Such model is critical for DFM, although one must decide whether to formulate a custom-made or to calibrate a chosen commercial model. Commercial cost packages as mentioned previously offer functionality that allows user to calibrate a cost framework with the product's own historical data, in order to tailor model to their specific financial and business requirements. However, the calibration process requires expert judgment. The quality of data as well as assumptions is all highly influential.

Activity based costing is a financial accounting technique frequently used for managerial accounting, that maps indirect engineering efforts and resource utilizations. Similar to other cost modeling approaches, cost drivers are first determined. Following that, sequence of manufacturing activities is mapped to generate a hierarchy of costs. Indirect cost, or overhead, is then allocated to activities based using cost drivers. ABC is extremely useful for indirect cost modeling.

The bottom-up or detailed cost estimation is the most obvious form of costing. In this approach, the costs of all sub-components in a product are determined. In the example of an aircraft landing gear, all the costs associated with actions and materials needed to manufacture it are collected. In its most primitive form, SAP is used to generate a Bill of Material (BOM), indicating all material costs and labors. Since such approach consists of gathering all cost information attributed to the cost of the final product, it is extremely information-intensive.

Even with SAP, the process is extremely difficult to implement, requiring continuous update with new data. The data is also difficult to manage.

An attempt to effectively utilize bottom-up cost estimation is the Genetic-Causal cost modeling principle.(Curran, Price and Raghunathan) This model adopts the principles of categorization (Genetic) and incorporates it with causality (Causal). Essentially, the concept of causality states that the cost of a subcomponent drives, or “causes” the cost of a larger component. Consequently, every component cost can be traced or built on a set of cost “reasons”. Using this model, an aircraft’s genetic makeup is first determined and classified, since cost is inherited from the design definition and production process. Causal cost drivers are then determined based on component dependencies and are linked accordingly. In essence, such technique illustrated how conceptual design parameters impact on cost, critical for DFM.

Top-down cost estimation is a finance-driven technique that determines a product’s should-cost. It is widely accepted that price-led costing is preferred to cost-plus pricing in a competitive market. One should, therefore, determine a product’s top line by market value. Given the profit margin that the firm wishes to achieve, the product should-cost could be calculated. The product is then broken into sub-components top-down forming levels of hierarchy, and assigning cost to each. Consequently, instead of allowing design engineering to set price, top-down techniques allow a company to make products acceptable by market.

Financial Catscans (Howarth) has been developed to incorporate PE into top-down cost estimation. Just as in PE, CER is first determined to describe the production cost based on technical parameters. Value Estimating Relationships (VER) is then determined, describing the

market value of an aircraft based on its profit-making attributes. Some market-related parameters selected are size, speed, range, safety, and comfort. Additional physical and legal constraints, such as speed boundaries and passenger limits set by Federal Aviation Regulation (FAR) are also determined. The intersections of these curves, including CER (technical-related), VER (market-related) and the limits defined the Financial Opportunity Spaces (FOSs). This space is the operating region in which the company will be profitable.

There are additional modeling techniques that integrate different cost estimation models. For example, a multi-model generator (MMG), created by van Tooren, aimed to establish a smooth link between parametric product model and bottom-up manufacturing costing. (van der Laan and van Tooren)

## **2.2 Review on cultural change**

As highlighted in Chapter 1, PZL Mielec's unique cultural identity presents additional challenges for instigating changes in an already complex defense conglomerate. However, effective and speedy changes must occur in order to reach the ambitious cost reduction goal set by the upper management. Lessons learned by other multinational corporations (MNC) and cultural change techniques will be reviewed for effective execution process development at PZL.

### **2.2.1 Why managers failed in Post-Soviet Russia**

Transformation in Post-Soviet Russia in the 1990s serve as a classic case study of a former communist state going through a period of unprecedented economic and organizational change. Companies strive to become competitive, market-oriented and flexible in order to remain relevant in the new free-market environment. At the same time, Russian managers and

executives find themselves competing in a new world that they are often ill-prepared for given their past economic orientation, philosophies and practices. A survey of 174 Russian managers was conducted to explore the primary causes of management failures, and offered specific lessons on management development (Longenecker).

Four main reasons emerged as the causes of managerial failure. First, managers are placed in leadership position despite the lack of prior managerial experience and lack of formal business training and education. Second, there existed an ability-skills gap around specific competencies, such as communication, marketing, planning and control skills. There also existed poor interpersonal skills required for conflict resolution and efficient organizational operations. Third is attitude and personality based, as managers often lack the ability and willingness to change and take risk.

A set of recommendations for developing a sustainable organization in Russia was also drawn from the surveys. These recommendations are applicable to other former Soviet bloc states as well. First, a MNC needs to resist the urge of rapid market entry, and takes extreme care in the process of hiring and promoting management personnel. Managers in the new organization also must present clearly defined roles, goals and duties, in contrast to the lack of accountabilities in former state-owned systems. Coaching and mentoring needed to become integral parts of the organization. Managers would be trained at very specific skill sets. Managers should be encouraged to take on risk-taking, action-oriented and decisive behaviors. At the same time, there needs to be regular and systematic review of managerial performance



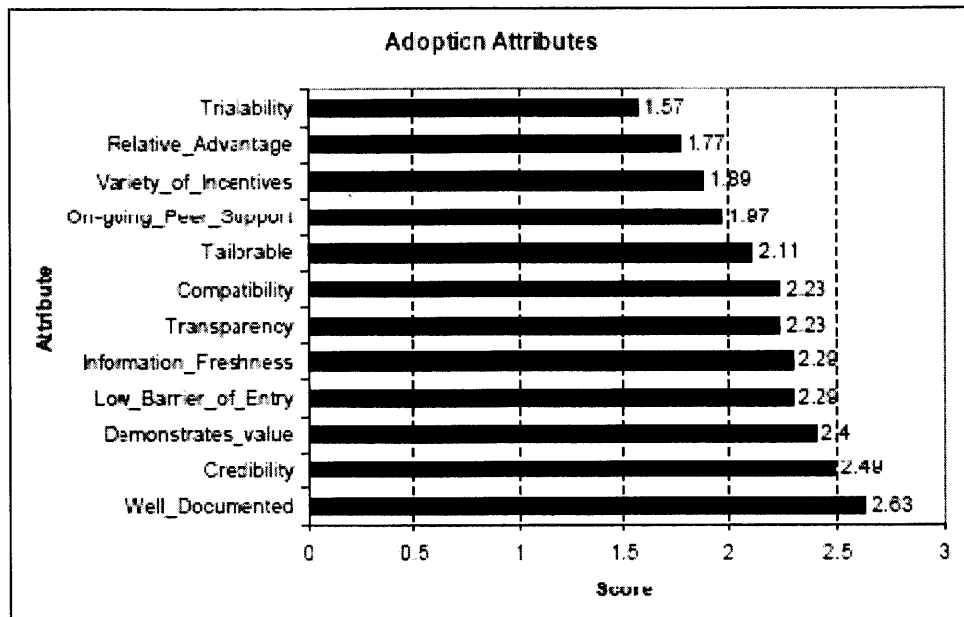
to drive continuous improvement. Lastly, a MNC should provide room for failure, as development requires time.

### **2.2.2 Cultural barriers for tool adoptions**

In every organization, including PZL, an extensive amount of time and money is spent on developing methodologies and tools to improve the systems engineering process.

Unfortunately, less is spent on addressing the organizational factors that can facilitate or hinder their adoption. This is partially due to technology centric approach to problem solving. Instead, an organization centric approach is needed.

A number of critical adoption factors were identified in literatures. (Farquhar and Surry) The key adoption factors include the need for low barrier of entry, ease of use and low risk of failure. The innovator will need to work with early adopters to satisfy their need and jumpstart diffusion, and provide vertical support structure to overcome targeted audiences' technophobia. A first-time trial success is also critical for building credibility. Most importantly, there needs to be an institutional advocacy, with credible commitment from policy setters. An adoption survey was conducted to a group of thirty-five system engineers in the defense industry. (Valerdi) Attributes were rated with three being the most critical factor (Figure 8).



**Figure 8: Ranking of adoption attributes (n=35)**

The most important attributes were documentation, credibility and value. Consequently, the driver, or the change agent, will need to have significant credibility and provided well-documented instruction and support. He will also need to understand the needs of the audience, develop a process that satisfies such needs, and market the key value of the process effectively.

### 2.2.3 Driving change in complex organizations

In their books, Chip and Dan Heath explains that driving changes in a complex organization requires the agent to simultaneously target the rational (Rider) and the emotional sides (Elephant).

To direct the Rider, the agent needs to analyze bright spots and replicate past success (Heath and Heath). He needs to provide specific behaviors and avoid big pictures in targeting the rational side of the audience. Lastly, he needs to provide Rider with a destination to show why it is worth it.

To motivate the Elephant, the agent needs to use physical or psychological stimuli to incite emotional responses. He needs to break down the change into small segments, so that the task appears less formidable. He also needs to cultivate a sense of identify and instill growth mindset.

Lastly, the agent needs to shape the path of change for both the Rider and the Elephant. He needs to change the environmental factors that influence behavior. He needs to encourage habitual behaviors that help to aid change since it does not tax the rider. The agent also needs to take advantage of the bandwagon effect. He needs to help spread encouraging behaviors as they could be contagious.

### **2.3 Summary**

State-of-the-art cost tracking technique has been presented. Chapter 4 will combine top-down and bottom-up techniques to develop a project identification and prioritization process using a centralized database. A good understanding of the cultural barriers for tool adoption is also critical to the success of the database. Lastly, different cultural change recommendation will be developed based on the factors outlined in Heath's theory.

## **Chapter 3. BEST PRACTICE CASE EXAMPLES**

In order to reach the ambitious cost reduction goal, PZL needs to focus on two key areas. First, it needs to have a well-structured cost reduction metrics and process. Second, it needs to have a well-developed execution plan that cultivates agents of change. UTC Otis is presented as a case study for cost tracking. ABB is presented to illustrate how a MNC enters transitioning economies and drives change.

### **3.1 UTC Otis**

The Otis Elevator Company is the world's largest manufacturer of vertical transportation systems today, with large market shares in elevators and escalators products. Founded in 1853 by Elisha Otis, pioneer of safety elevator, it was acquired by United Technologies in 1976 and is a wholly-owned subsidiary. Within UTC, Otis has been at the forefront of cost tracking, helping it to become one of the best financial performers among its peers. It utilizes a top-down cost estimation and tracking process that dictates product design.

Its cost targeting philosophy emphasizes on goals that reflect business and the market as oppose to engineering requirements.(UTC Otis) Instead of designing a product that satisfies the market 100%, only selected functions are included to satisfy the chosen segment. The cost goals are constantly benchmarked against competitors, ensuring that it achieves the best-in-class. It is updated continuously, to reflect change in resource availability and cost reduction opportunities. The process of target creation starts with determining the baseline product configuration with highest volume. This step helps to eliminate ambiguities associated with product options. The next is a top-down evaluation based on marketing data and benchmarking.

The process finishes with supply chain, design and manufacturing working to obtain product data bottom-up. A link between the last two processes is established by Finance, and translated into cost targets. Having cross-functional involvement in costing process is critical for accuracy.

After targets are established, multiple cost tracking techniques are utilized. A four-column table is established to measure performance. Metrics is the least utilized technique for most companies, but is also the most indispensable toolset for cost tracking. At Otis, a product B that is designed based on product A would have table with the following columns:

- Column 1: cost of the product A baseline, developed and fixed during the initial phase of costing analysis
- Column 2: updated cost data of product A, at least quarterly; this column is missing if A is discontinued
- Column 3: Cost target of product B, develop during initial phase of costing analysis
- Column 4: updated cost target of product B

Cost drifting is an integral part of product development. For most commercial products, cost could be first accepted and lowered through reduction efforts later during production. Unfortunately, products with high design cost or stringent certification requirements do not enjoy the same luxury. To minimize drifting, cost risks would need to be prioritized during target creation phase. One should group component risks into low, medium and high, and establish initial target by summing low and medium risk components. As cost drifts, one should always work on high risk issues first. Product features should also be re-examined assiduously. Non-critical ones should either be eliminated, or offered at a premium.

Another powerful tool used by Otis to reduced cost is the “Octopus Fishing” technique. (UTC Otis) Pioneered at Otis Japan Shibayama plant, it is a top-down cost reduction process that benchmarks cost data and prioritizes reduction efforts. Instead of focusing on every tentacle, this methodology concentrates on the larger branches. It is used both on existing products as well as during conceptual phase of new product. However, since cost is generally locked in after design phase (Fine), it is generally used at Otis during early stage of product development.

At Otis, “Octopus Fishing” is a two-week Kaizen event that occurs every year. Five different elevators from Otis factories around the world are delivered to headquarters. These elevators share similar fundamental characteristics, and possess the critical parameters under analysis. For example, they would be in the same weight class, but used different instrument panels that are sourced from different suppliers.

After elevators are transported to the main plant, the elevators are broken down to subsystems, such as ropes, car, controller, and counterweights. The grouping should be done in a way that minimizes interdependence. Consequently, a reduction effort on one subsystem would not impact on the cost of different subsystems.

During the first week, Finance departments work with design engineers from different factories to collect component cost data. A formal cross-functional Finance team could also be formed to ensure prompt response to questions related to data entry and verification. The cost figures are then grouped together and assigned to individual subsystems. This is a laborious process. Data could be collected from SAP, or be tracked down from suppliers or home factory

site, each could offer conflicting data point. Nevertheless, its accuracy is critical for establishing good benchmarks. Grouping elevators with different architectures into the same subsystem family could also be challenging. Designers would play an important role in translating components into financial figures. If consensus on grouping cannot be reached among elevators, components are regrouped. To maximize visual impact, the elevators are broken down physically into these subsystems, with price tags placing next to them.

At the beginning of second week, three formal global cross-functional teams: Manufacturing, Supply-chain, and Electronics, are formed. Participants on each team consist of representatives from five operation divisions: design, marketing, field installation, supply chain, and finance. Furthermore, every team requires at least one supply-chain and one design engineer, in order to provide prompt evaluation of brainstormed ideas. The subsystems are assigned to the three teams based on its leading characteristics. A car door, for example, may be manufactured by four out of five factories, and therefore, is assigned to Manufacturing team. However, the fifth factory may have outsourced its door at a lower cost. The supply-chain representative on the team could immediately evaluate the feasibility of outsourcing.

The next stage of the analysis consists of intense brainstorming sessions through benchmarking. For each subsystem group, elevator with lowest cost becomes the benchmark. The four with higher cost are analyzed using the TPS Five Whys. Components are added or removed from a subsystem with care, to insure that the modifications recommended do not impact other subsystem. At the end of Kaizen event, a list of recommendations is provided for every subsystem, grouped into short-term and long-term goals. The aggregated list is then

provided to local managers for prioritizations and implementations. Since there are additional site-specific technical, cultural and political limitations at every factories, only two-thirds of the recommendations are expected to be implemented. Historically, the global and cross-functional natures of the event have helped to generate three times as many ideas as conventional ones. Consequently, global participation, in addition to top-down cost benchmarking, is the key to the success of “Octopus Fishing”.

### **3.2 ABB**

Asea Brown Boveri, ABB, is a multinational corporation with presence in more than 100 countries. Its history of growth has been strongly associated with the acquisition of competitors across different boundaries in order to stimulate rapid growth and market access, as well as creating global economies of scale in a highly decentralized organization. Under its first CEO, Percy Barnevik, ABB embraced a vision that was said to “combine global scale and world-class technology with deep roots in local market”.(Taylor)

Since 1989, ABB has been actively acquiring assets in emerging economies such as China and Poland. Different market entry strategies and post-acquisition integrations were implemented with marked differences in results.(Hardy, Currie and Ye)

ABB’s entry strategy in Wroclaw, Poland was “big bang” in nature, in the sense that all the assets were acquired as a result of a one-off negotiation. It was consistent with its previous involvement in Central and Eastern Europe in that it was precise about which enterprises or parts of these it was willing to acquire. Consequently, it resulted in a clear and straightforward outcome in ownership and responsibilities linkages. ABB also showed little enthusiasm for



networking in the locality, and subsequently its roots in Wroclaw were shallow and token. The key reason is that the Polish central government remains the key decision maker in its state-owned enterprise, or SOE, divestiture, with local government having minimal power. Consequently, the negotiation for buying into an existing factory occurred at the national level circumvented the local structure.

In Xiamen, China, on the other hand, ABB's involvement had been through joint ventures with key local partners, where its control is less than complete. Further, they have relied extensively on local suppliers. The local state had high degree of autonomy and had direct ownership of local assets, both land and finance.

The post-acquisition integration processes also differed at the two locations. In Wroclaw, ABB encountered similar challenges that were universal to the 1990s Poland. The management team acquired was characterized as passive, as they were constrained from above and below under communism. They were constrained in decision making by the imposed nationally determined targets and quotas from ministries. From below, Works Councils, similar to labor union in the US had significant power, including the right to dismiss managers. ABB had to secure the agreement of the Works Council for privatization that was by no means automatic. Managers also had scant knowledge of western-style managerial functions that prevailed in competitive markets. Being in a captive markets, managers paid little attention to quality control. Being under a controlled product price, they did not understand costs and western-style accounting. Human resource management did not exist, and provided little services in labor training.

To deal with the deep-rooted nature of workplace rigidities and legacies in Poland, ABB transformed the management culture through “shock-therapy”. The company had a group of global managers that were trained through rotational program. Shock troops comprising of ABB global managers and consultants were sent to administer a short sharp shock to induce rapid change. For example, ABB corporate-approved solutions were transferred and forcibly implemented into Polish firm, immediately replacing the former well-established routines, recipes, procedures and structure of the formerly centrally planned company. Furthermore, no initial prognosis of existing local conditions was done. The imposition of headquarters’ rules was done in a purely unidirectional manner.

ABB also developed “agents of change” to run the local firm once the shock agents leave through a two-fold process. The first was selecting former SOE managers most likely to adopt and change, and enrolling them through intensive ABB management training. They were also sent on benchmarking tours at other ABB facilities. The second element was to improve remuneration and status of highly qualified managers. They were provided with material incentives and prestige, such as large wage increase, company cars and extensive opportunities for foreign travel. Doing so help to retain qualified employees and create an inspirational goal for rest of the organization. Since acquisition, the managers exhibited little allegiance or nostalgia for the previous SOE. On the other hand, they exhibited increasing accountability. Lastly, as an attempt to disembodify from legacy constraints, ABB did not recruit directly from local universities.

Due to the nature of market-entry, a more organic approach was taken in Xiamen China. ABB collaborated very closely with local universities in recruiting. The training of managers in Xiamen took place in-house and in collaboration with prestigious education institutes in China and abroad. Many managers were sent to prestigious MBA programs, and workers are sent to headquarter for key skill training.

### **3.3 Summary**

Two best practices examples have been presented in this chapter. UTC Otis' Octopus Fishing technique will serve as an example for Kaizen events at PZL.

ABB demonstrated reflexivity and adaptability in crossing national boundaries. In Poland where legacy culture embedded strongly in the existing SOE, a more forceful approach was taken to expedite integration. While ABB's effort to disconnect Wroclaw facility from locality may be too extreme, it is not without merit. It may be an effective way to transform an organization with deeply-rooted history. Furthermore, its emphasis on the development of agents of change could be emulated at PZL.

## **Chapter 4. PROJECT IDENTIFICATION AND PRIORITIZATION PROCESS**

A project identification and prioritization process will be described to effectively distribute limited resources to cost reduction projects. A top-down finance driven framework will first be established using M28 and its competitors cost breakdowns. A bottom-up project generation framework will then be described. The chapter will conclude by linking the two frameworks to develop the concept collection database.

### **4.1 Current process**

The current process is summarized below:

- Upper management sets reduction targets for procurement and manufacturing groups
- Different functional groups brainstorm project ideas
  - Suggestions provided by customers
  - Suggestions generated within procurement/mfg group; they choose their biggest problems to target, that often result in fire-fighting instead of long-term planning
- Individual department evaluates project financial value (e.g. procurement group's five-gate process), but not linked to the 28% reduction target
- Optimization Team picks and targets projects, but the exact methods of selection are unclear
- Bottom up, continuous approach taken by Optimization Team

The Pitfalls are:

- Miss or delay other projects with greater cost-saving potentials

- Insufficient resources available to target overwhelming number of projects
- Insufficient resources dedicated to each project, resulting in less-than-optimal cost saving
- Lack of ownerships or follow-ups, causing completion problems
- Continuous approach: new project ideas seem more attractive than old ones
- Continuous approach: lots of meetings and resource drain: hard to set up sustainable process
- Lack of formal process to enforce the habit of using cross-functional teams
- Invest in projects that improve functionality and manufacturability, not cost. In most projects, the three parameters are closely interrelated. However, a project that has maximal impact on manufacturability improvement may have minimal effect on cost reduction. Consequently, when selecting projects from a wide task pool without clear cost metrics, the Optimization Team may miss the ones with greatest cost reduction potentials
- Lose focus on the 28% reduction target
- Trapped in engineering details

The following discussion begins with M28 cost break down. A set of recommendations will then be provided based on cost structure to address the listed concerns.

## **4.2 Top-down approach: M28 and competitors cost structures**

To understand the cost structures of competing turboprop STOL aircrafts, the structure of M28 will first be presented. The challenges of data collections will then be discussed. The material and labor cost of M28 will be benchmarked against competitors.

### **4.2.1 M28 architecture and production process**

The major M28 sub-assemblies are shown in Figure 9. The assembly process consists of 22 stations with a total production time of approximately 150 days (Figure 10). Each sub-components are individually assembled before joining together to form the major subassembly. The right, left and tail plane are joined together to form empennage assembly. The forward, central and rear fuselages are joined together to form fuselage assembly, and serves as the major structure. After fuselage is formed, centerwing and landing gear are assembled onto the structure. Left and right wing is then attached to the centerwing, followed by empennage being attached to the rear fuselage. Finally, the interiors furnishings are installed, followed by painting before the plane is rolled out to hanger for final testing and calibration.

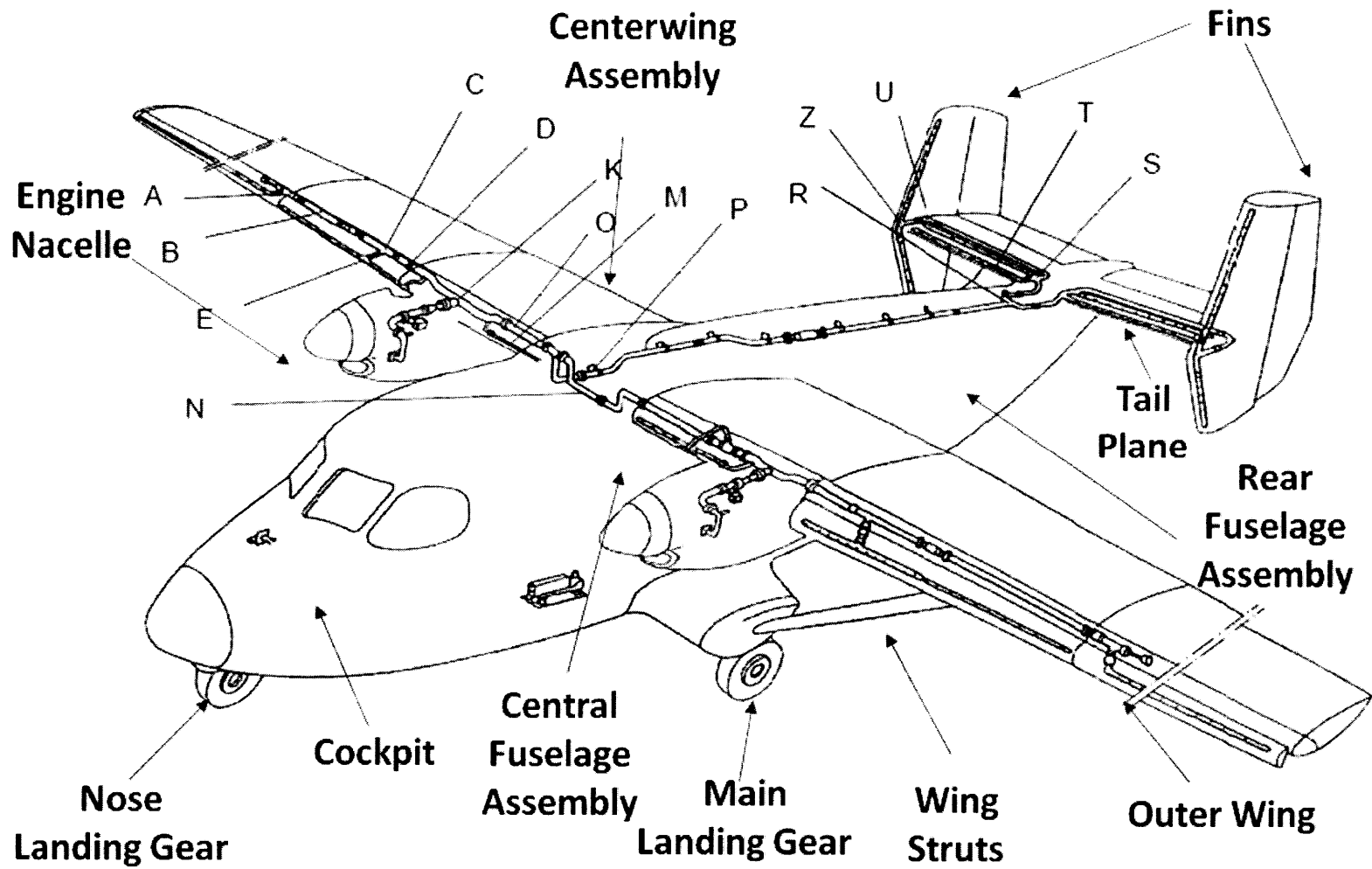


Figure 9: M28 structure

		Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Station Number	English Description	Day																															
140	Tail plane	36												■																			
130	Left fin	33												■																			
120	Right fin	33												■																			
150	Empennage Assembly	1	↓																														
100	Right outer wing	74	■			■																											
40	Rear fuselage assembly	25	■							■																							
20	Forward fuselage assembly (cockpit)	39	■						■																								
30	Central fuselage assembly	40	■							■																							
10	Centerwing assembly	69	■											■																			
110	Left outer wing	74	■			■																											
50	Fuselage assembly	10												■																			
60	Fuselage+centerwing	5												■																			
70	Fuselage+centerwing+landing gears (undercarrier)	2												■																			
80	Optional/Operational Equipments (eg. GPS, instrument panel) installation	10												■																			
90	Water test	3												■																			
160	Outer wings and wing struts installation	1	↓																														
170	Empennage installation	1	↓																														
180	Engine nacelle installation	16												■																			
190	Interior installation	10												■																			
200	Fuel system installation	15												■																			
210	Painting	10												■																			
220	Hanger+flight test+navigation device calibration	10												■																			
Total		152																															

Figure 10: M28 Gantt chart



#### 4.2.2 M28 cost structure

M28 cost data has been gathered and analyzed. Serving as foundation, accurate cost data is critical for any cost reduction effort. The total cost of aircraft is determined. Including margin, the M28 is currently priced significantly above competing aircrafts. 48% of total cost is labor cost, and the remaining cost is material cost. Assuming a batch size of five aircrafts, the direct labor hours are determined and are allocated to each aircraft. Overhead is not available for data gathering. Fixtures amortization and depreciation are also not included. Given the long history of M28 aircraft, the initial capital expenditure on fixtures has already been depreciated.

To allocate cost, the product cost is segmented based on structure type. The eight groups are: fuselage, wings, empennage, undercarriage, power plant, avionics and electronics, interior and ducting, and painting. The cost breakdowns are shown in the following three figures.

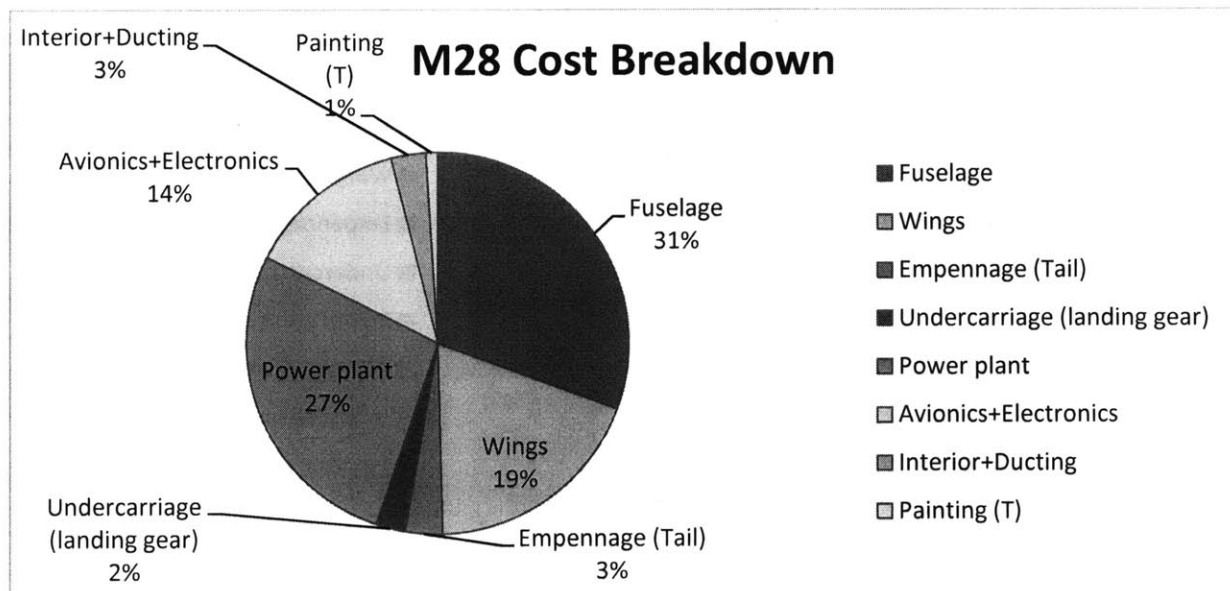


Figure 11: M28 cost breakdown (labor and material)

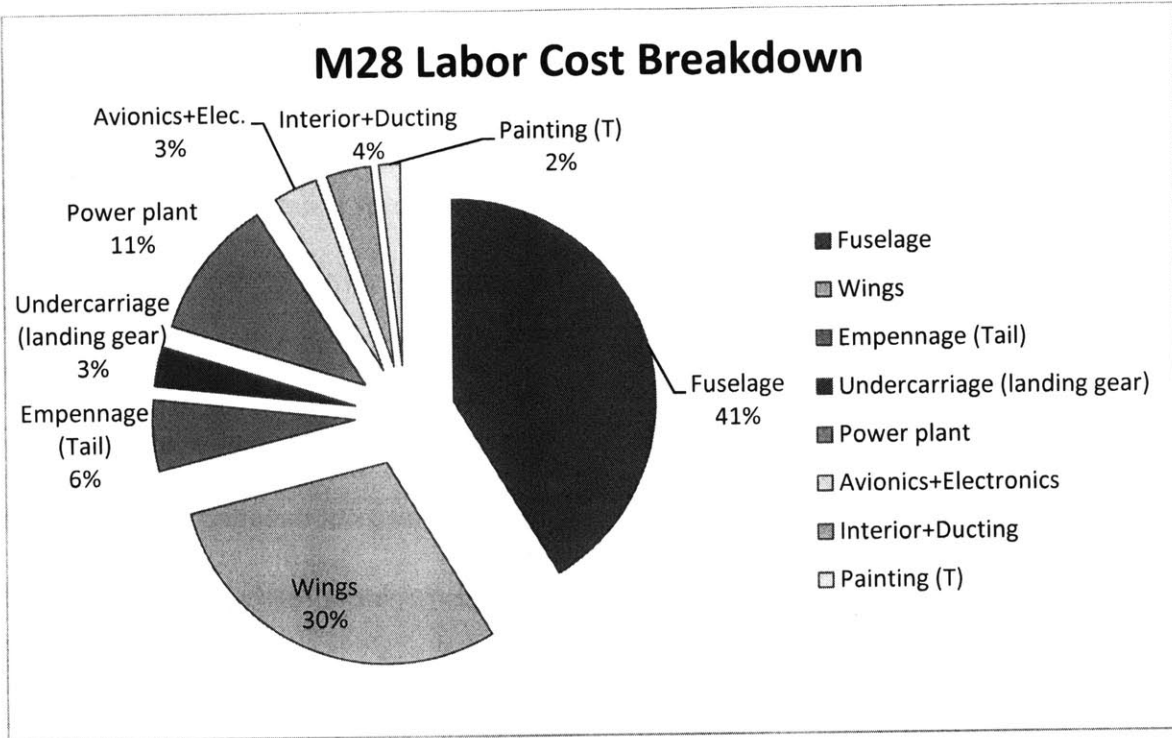


Figure 12: M28 labor cost breakdown

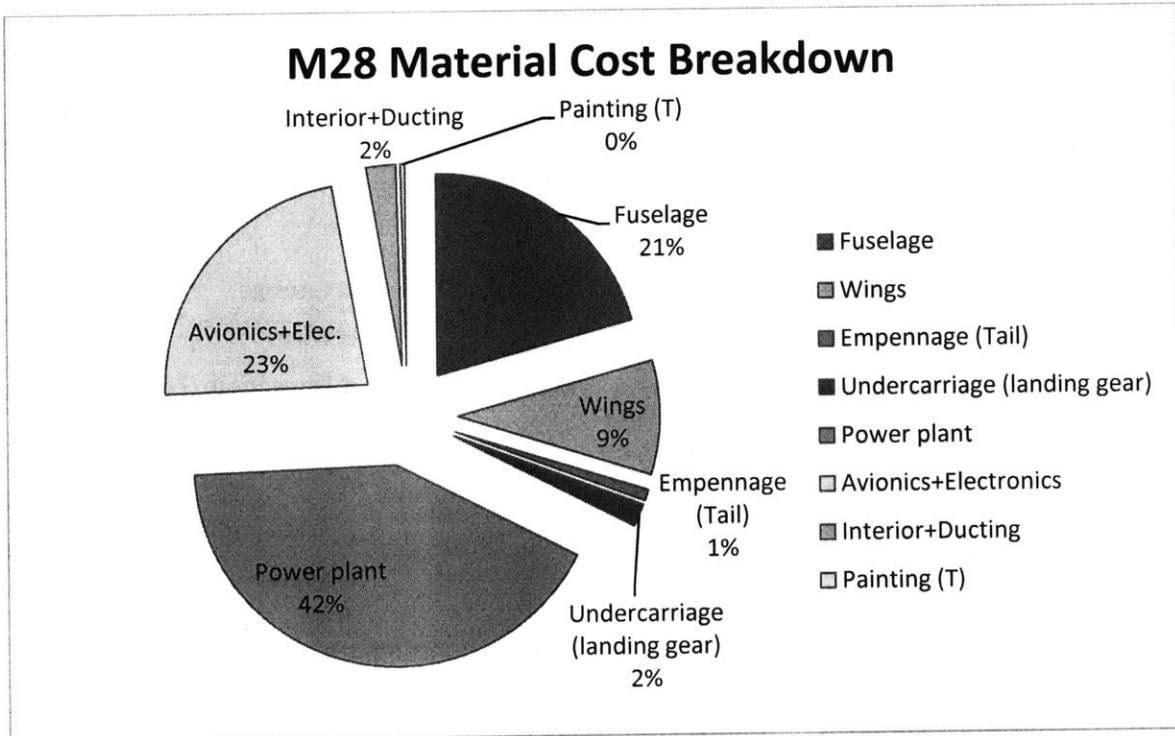


Figure 13: M28 material cost breakdown

Data shows that the highest cost structures are fuselage, power plant, wings, avionics and electronics. Specifically, fuselage, wings, power plant have the highest labor cost content. As described earlier, M28 is currently manufactured in a prototypical way, requiring intensive manual labor. Fuselage and wing contribute to the majority of the airframe structure and have over 50% of the total production time. Both setup and working time are also highest among all the structures. While power plant is mainly PT-6A engine purchased from Pratt and Whitney, its structural complexity required significant amount of installation time. It ranks third highest in setup and work time required among all the structures.

The structures with highest material cost are power plant, avionics and electronics, fuselage and wings structure. It is not surprising that power plant contributes to over 40% of total material cost, as it is the most expensive component on any types of aircraft. As an engine expert joked, "airplane is simply engines with wings attached to it." Avionics and electronics also contribute to 23% of total material cost. They are mostly purchased, with significant margins gained by manufacturers and distributors. Many of M28's competitors are considering glass cockpits. While a traditional cockpit relies on numerous mechanical gauges to display information, a glass cockpit features electronic instrument displays integrated by a flight management system. The system provides pilot with the flexibility to select flight information being display. Consequently, glass cockpit greatly reduces pilot training time and simplifies aircraft operation. With the advent of glass cockpit avionics, the avionics cost would expect to increase further in the near future.

With a well-understood M28 cost structure, cost reduction projects could be prioritized based on their material and labor cost.

#### 4.2.3 Competitive data gathering and associated challenges

Competitor's cost data are gathered via three methods:

- **Market intelligence reports.** Market intelligence agencies, such as Forecast International, Jane's Information Group and Airframer, offer reports with detailed breakdown of components equipped on competing aircrafts including manufacturer information. Furthermore, they provide market pricing report of high-valued subassembly such as PT6A engine. Market intelligence reports are critical for this analysis. On the other hand, there are concerns regarding the accuracies of the pricing reports. For example, the M28 engine price indicated on the report is slightly lower than the price quotation received by PZL
- **Price quotations from suppliers.** With component lists of competing aircrafts, price quotations for these parts are submitted to suppliers. There are several challenges associated with this method of data gathering. First, there are relatively low response rates from suppliers. Furthermore, many components have become obsolete with production and sales discontinued. Lastly, the competing aircraft manufacturers may receive volume, LTA, and other forms of discounts due to well-established long-term relationships. As a researcher without established working relationships, the data received may be at market value, a level often greater than 25% of the actual price received by aircraft manufacturers

- **Publications and marketing materials.** News report and trade journals provide additional information on products, including development history of the aircraft, the location of manufacturing facilities and joint-collaboration activities with suppliers. Corporate marketing materials also provide additional information about the product

In addition to the difficulties outlined above, additional challenges exist in competitive data gathering process. Information relating to labor cost is largely unavailable. While labor rate could be approximated by the location of the factories, the actual wage may vary by company, and internally by functional groups. The labor hours that vary by learning curve are trade secrets missing from public domain. When estimating competitors' material cost, the price discounts received by competing manufacturers may be less than 25% of the quoted price. Given the challenges in gathering labor and material cost data, a qualitative discussion with limited data will be presented in the following sections.

#### **4.2.4 Labor cost benchmarking and reduction opportunities**

Based on competitor's data, M28's labor cost could be reduced by decreasing labor rate, increasing batch size, or reducing labor hour per aircraft. Labor cost can also be reduced by factory and manufacturing processes improvement. However, due to language difficulties, they are out of the scope of this thesis.

The first potential for labor cost reduction is on reducing labor rate. Figure 14 outlines the global average airframe labor rate in 2008 and 2009. While Africa and Latin America have the lowest labor rates, outsourcing has so far been blocked by several factors. High legal and political risks of doing business in sub-Saharan Africa serve as deterrent to potential entrants.

With limited amount of aerospace manufacturers in both regions, the technicians lack the resources needed for training. Consequently, since airframe production has a relatively steep learning curve, the services provided by these two regions may be of lower qualities than other locations. However, as leading aircraft manufacturers including Brazilian Embraer continue to grow, the workforce quality will improve, potentially drive up labor rate.

Europe has the most expensive labor rate, while North America and Middle East have similar mid-range rate. On the other hand, Middle East could be very attractive to European carriers, as the physical proximity ease operational integration. With a booming Middle East market that results in seemingly insatiable demand for aircrafts, setting up factories in the region could provide offset requirements.

The regions with greatest wage increase are India and Eastern Europe. With new aviation manufacturing activities in India that compete for limited labor resource, India's labor rate rises to the level of well-developed Asian market such as China. At the same time, as additional Eastern European nations enter the European Union, increased worker mobility will continue to drive up labor rate to the level of Western Europe.

	2008	2009	% Change
Western Europe	\$74	\$70	-5%
North America	\$54	\$56	4%
Middle East	\$56	\$56	0%
Latin America	\$34	\$36	6%
India	\$31	\$41	32%
Eastern Europe	\$54	\$64	19%
China	\$44	\$44	0%
Asia-Pacific	\$44	\$45	2%
Africa	\$37	\$37	0%
<b>World Average</b>	<b>\$48</b>	<b>\$50</b>	<b>5%</b>

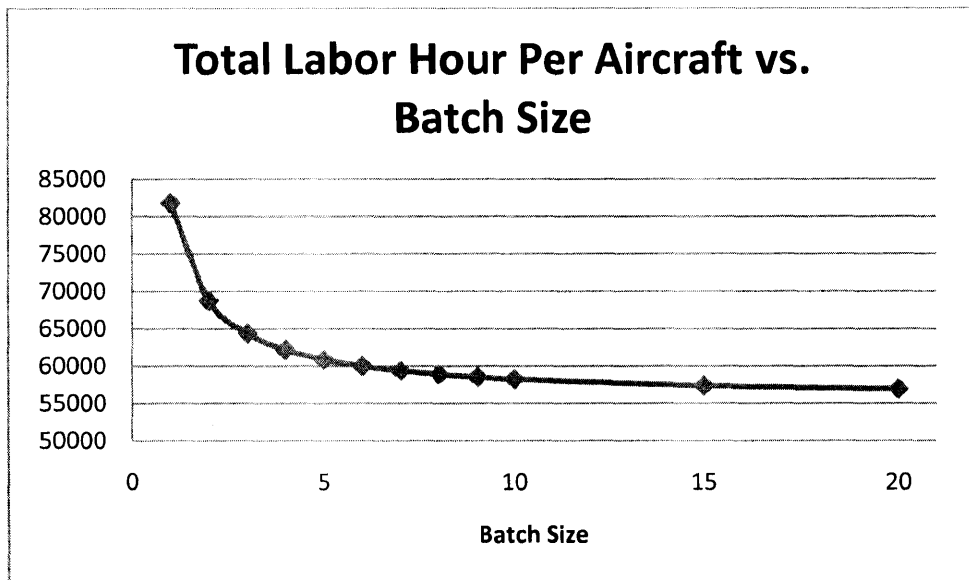
**Figure 14: Estimated billable hourly rates for airframe labor by region (Canada)**

Competing product Twin Otter 400 is manufactured in Canada with a projected labor rate of \$56 per hour. A large percentage of RUAG 228 New Generation subassemblies are manufactured in India with a projected rate of \$41 per hour. Lastly, the new model CASA C-212 Aviocar is mainly built in Indonesia with labor rate of \$45 per hour. PZL, in contrast, manufactures M28 in Poland, a region with an average wage of approximately \$45 per hour. Given the highly desirable skill sets that Sikorsky could offer to its employees, the workers are paid at or below average wage. A less-than-average labor rate results in high workforce turnover. In fact, many mechanics view employment at PZL as an opportunity to receive high quality training before moving on to better paid jobs with local manufacturers. Given the fact that PZL already has a competitive labor rate that is market level, there is very little room for further wage reduction. Replacing the highly skilled Polish workforce with a cheaper one at another region is also not an option. Other cost reduction opportunities should be investigated instead.

Increasing batch size could provide the economies of scale needed to reduce labor cost. Currently, assuming a batch size of five, 8% of total labor hours are setup time allocated to each aircraft. This setup time only captures direct labor setup. As mentioned previously, overhead and indirect labor data were not available. While there is cost saving potential there as well, it is not included in this discussion.

As illustrated by Figure 15, focusing solely on work time and setup time from direct labor, increasing batch size from five to ten will reduce total labor hours by 4%. Conversely, reducing batch size from five to two can increase labor hours by 13%. While the economies of

scale diminishes with larger batch size, increasing the size from the current level with greatly reduce labor cost. Unfortunately, the current demand for M28 is only twelve units per year. In the past years in which demand is less than six units, a batch size of one is used, consequently driving up cost. As this analysis shows, high demand is needed to establish economy of scale needed to reduce cost. On the other hand, the demand is partially limited by the prohibitive cost of the aircraft. One solution is to first reduce price, potentially below the breakeven point to drive up volume. As cost is reduced with increase number of orders, the margin will increase as a result.



**Figure 15: Total labor hour (work time + direct labor setup) per aircraft vs. batch size**

Lastly, labor cost could be reduced by minimizing the remaining 92% processing and assembly time. Compare to its competitors, M28 is a relatively mature product with well-established manufacturing process and skilled labor force. While competing products have a longer history of total sales, all three manufacturers are rolling out new product generations



with significant design changes. Consequently, the competitors are facing with a longer initial labor hours with steep learning curves. As their manufacturing process become mature, their labor costs will be further reduced, allowing additional opportunities for price reductions.

While PZL has a mature production process, it is craft production and remains highly labor intensive. On the other hand, the competing aircraft manufacturers have invested significant capital in modernizing their manufacturing process. In the following chapter, automation will be recommended as one potential solution for reducing labor cost. All labor cost reduction opportunities should be carefully considered.

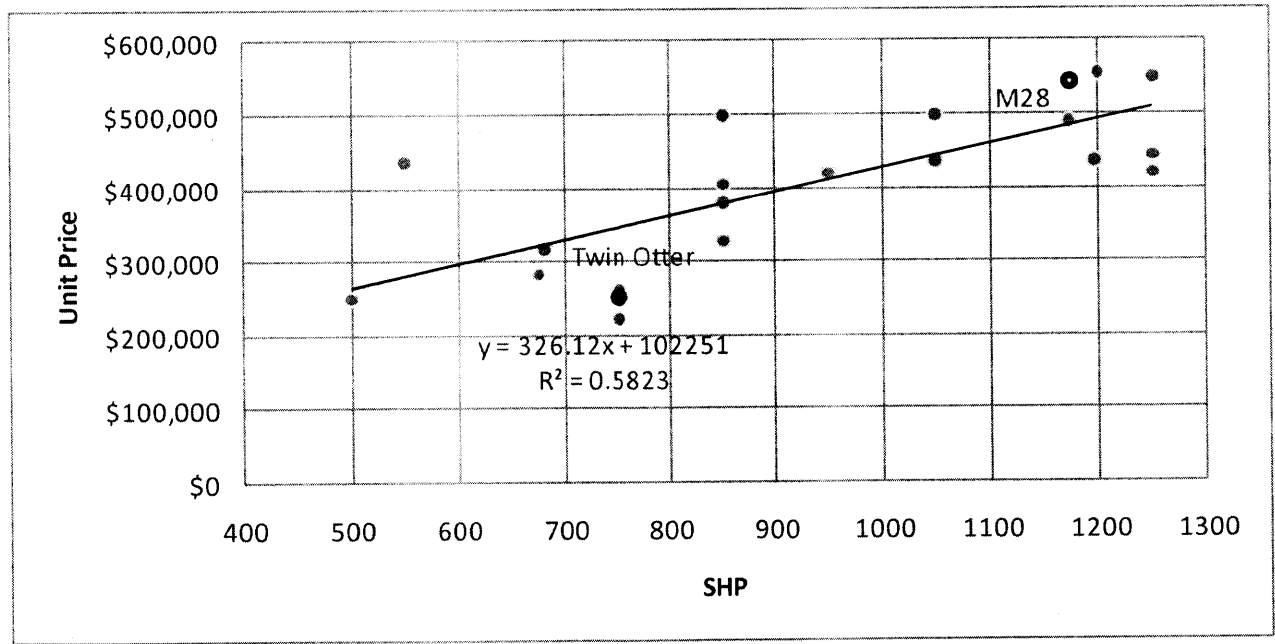
#### **4.2.5 Material cost benchmarking and reduction opportunities**

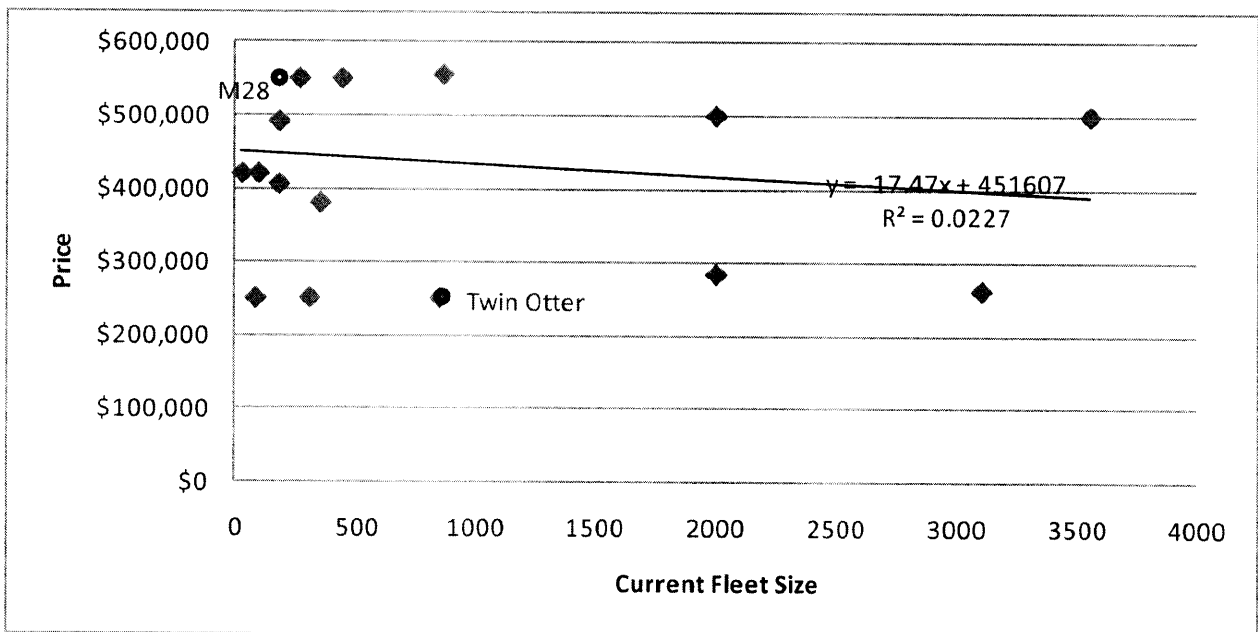
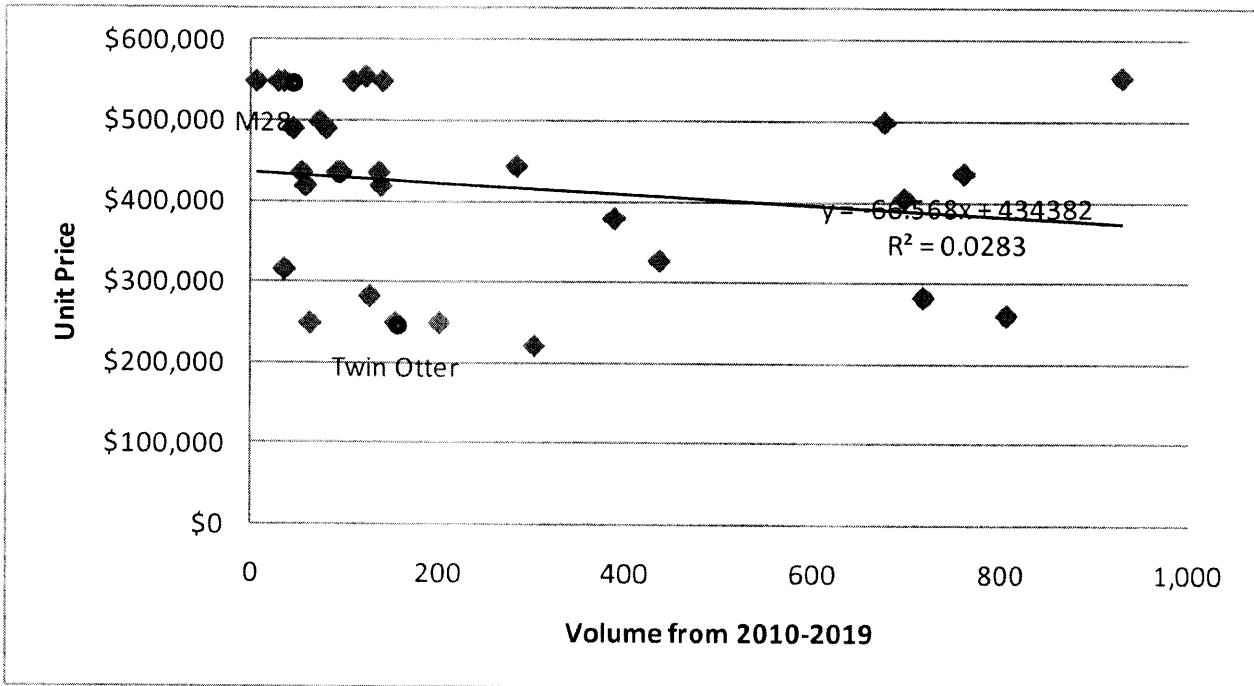
As shown by the cost structure breakdown, the power plant contributes to a significant percentage of total material cost. M28 and Twin Otter use Pratt and Whitney Canada PT6A engines, while Dornier 228 and CASA C-212 use Garret AiResearch TPE331 engine, also under license from Honeywell. Both engines have similar performance capabilities are generally considered interchangeable. Each engine also has different classes of shaft horsepower (SHP) performances that are priced differently.

The pricing of engine generally depends on three factors: performance, volume and existing fleet size. Better SHP performances generally translate to higher prices. A greater number of engines ordered will provide engine producer the economy of scale needed to reduce cost. The cost saving will be passed on to the aircraft manufacturers with lower price points. A larger fleet size also translates to a bigger after-sales market. Engine manufacturers make significant amount of profit from overhaul and maintenance services. Furthermore, a

large fleet size by a leading aerospace company functions an excellent marketing tool for the engine. Consequently, with a large existing fleet, the aircraft manufacturer has significant leverage in negotiating for better pricing for future engine orders.

PT6A pricing data has been gathered (Forecast Internationals). Regression models are formulated based on SHP, current fleet size, and total forecasted volume from 2010-2019 (Figure 16). While there is strong correlation between pricing and performance, the correlation with fleet size and volume is relatively low, with p-values greater than 0.05. It may due to the fact that engine production is highly customized. Consequently, high order volume does not translate to cost reduction due to economy of scale. Existing fleet size may also be irrelevant as new aircraft requires a new generation of engines with radical redesign. Consequently, there is exist minimal economy of scale in the after-sales market.





**Figure 16: PT6A pricing regression with respect to SHP, volume and fleet size**

Using the regression between SHP and price, M28 engine is priced 19% above market, while Twin Otter receives a price that is 28% below market value. The underpriced engine may

enable the aggressive pricing of Twin Otter. If M28 were to receive market price, there would be significant saving per aircraft. Consequently, the most costly component also has the highest cost saving potential. Both CASA and RUAG receive market price for TPE331 engines.

As a newly acquired subsidiary of UTC, PZL should have significant leverage in negotiating better pricing with Pratt and Whitney Canada, its sister company. A large portion of Pratt revenue derives from after-market services. Instead of charging a high transfer price for engines, P&W and PZL should collaborate in maximizing the number of M28 and engines in operation, consequently grew the after-sales business. In order to establish effective transfer pricing, the upper management of both divisions will need to coordinate in establishing pricing strategy that is beneficial for the parent company.

Twin Otter may also commands a better pricing due to the size of its engine order. In contrast to M28, Twin Otter currently has at least twice the build order every year. M28 purchases much fewer than the volume needed to receive pricing discounts. Similar to labor cost reduction, building up economy of scale is critical in reducing material cost. PZL could first suppress M28 price to drive up market demand, and then use the cost reduction in engine to improve its margin. With a higher volume, PZL could also establish long term agreement with its sister company to keep engine price low.

The second highest material cost contributor is avionics and electronics, accounting for 23% of total material cost. Commodity purchasing strategy recommended for cost reduction will be discussed at a later chapter. M28 avionics will first be benchmarked against competitors in the following discussion.

At a sub-component level, individual avionics and electronics contribute to less than 2% of total cost. The most expensive components are Electronic Flight Instrument System (EFIS) display, Terrain Collision and Avoidance Systems (TCAS) and triple axis automatic pilot system. The prices of these components are similar to corresponding components used by competitors. However, aggregate pricing differentials accounts for the cost differences among aircraft models.

Both Twin Otter Series 400 and RUAG 228 New Generations are providing glass cockpits solutions. While the M28 cost structure listed only includes traditional avionics, PZL also offers additional models equipped glass cockpit avionics. The new model consists of individual component upgrades that further drives up avionics material cost. Substantial redesign was avoided to eliminate the need for requalification.

On the other hand, the developments of new Twin Otter and RUAG series include radical redesigns with access to greater avionics options. Understanding that substantial upgrades are required to satisfy customers' demand, managements include re-qualification costs in the research and development budgets. Consequently, Viking Air replaces traditional avionics with Honeywell Primus Apex all-in-one avionics solutions. On the one hand, all-in-one solutions prevent components substitutions, and limit the customization options available to end-users. However, customization has becoming less valuable as price of high performance avionics continue to decrease. On the other hand, bundling allows Viking Air to purchase avionics solution for \$250k, an amount significantly less than the total cost of M28 traditional avionics.

In summary, avionics cost could be reduced through redesign that allow greater access to avionics options. Bundling may provide a high performance low cost solution. All avionics components will be prioritized based on their costs, and benchmarked against competitors for better solutions.

The M28 cost structure has been presented and benchmarked against competitors. A project generation process will be needed to provide sufficient projects for cost reduction of expensive components.

#### **4.3 Bottom-up approach: project generations recommendations**

The current list of cost-reduction projects are generated organically based on engineering requirements. As mentioned in an earlier chapter, M28 production is a joint effort among the manufacturing, design and procurement organizations. The design group implements necessary but minimal design changes. The procurement group purchases raw materials, sub-assemblies and electronics. The manufacturing group manufactures aircraft based on the newly specified design. Currently, the three organizations submit cost-reduction project proposals to the M28 Optimization Team. A designer may want to replace the current avionics with updated glass cockpit avionics. A buyer may need to resource a certain forging component as the manufacturer became bankrupted. A factory team lead responsible for wire harnesses may want to purchase new tools to improve productivity. While all of these projects are critical for the continuous improvement of M28 manufacturing process, they are purely engineering based. Many of the proposals may have limited impact on reducing cost. Removing the non-cost effective ones, the number of projects proposals remains is highly limited. The

bottom-up organic approach is critical for empowering the employees on the floor to instigate continuous improvement. However, a more proactive cost-oriented guidance must be provided.

To increase the number of project generated, PZL should:

- **Drive project generation in maximum cost saving activities.** Instead of functioning solely as a receiver of projects from different functional organizations, the Optimization Team should actively drive and manage project generation. The team should rely on the top-down cost framework to manage bottom-up project generation. For example, the high cost component, such as engine has the greatest saving potentials. The Team should insure sufficient resources are dedicated on engine cost reduction, with a project owner that has adequate power to negotiate at the appropriate level of the organization. While a low-level buyer may come up with a novel procurement pricing structure, the negotiation would most likely fail if she was to be the sole owner of the project. She lacks the power and the network needed to be persuasive. The failure, due not to the feasibility of the recommendation, could cause the project to be dismissed immediately. However, if the Team, realizing the potential from the top-down analysis, were to invest additional human capital to insure continuity of the project, the impact could be significant. Instead of focusing on other non-value-added projects, the Team should focus cross-functional brainstorming sessions on engine price reduction. By elevating the project responsibility and bringing together key managers in designs, procurement and finance from Pratt and Whitney and Sikorsky, an optimal transfer price may be determined

- **Implement systematic cost-reduction approaches.** There are high level themes that could be used to guide project generations. Specifically, one could focus on reducing labor cost in the manufacturing organization, reducing material cost in the procurement organization through commodity purchasing strategy, and leading Kaizen events that sponsor redesign. The three areas will be discussed in-detail in the following chapters
- **Promote innovative thinking.** Outside-the-box thinking is critical in generating breakthrough cost reduction projects. One of the largest obstacles faced by M28 redesign is the prohibitive re-qualification cost. However, this cost is poorly understood throughout the organization. Nevertheless, the mindset that re-qualification should be avoided limits innovative redesign proposals. PZL and the Optimization Team should first dedicate resources to understand the qualification requirement and cost and educate the PZL organization on the result. Instead of writing off all redesign proposals, they should be systematically evaluated through a cost-benefit analysis. Similar outside-the-box thinking should be promoted throughout the organization, especially as PZL faces a very different post-socialist and global economic climate
- **Raise product awareness.** Increase the number of participants in the M28 cost reduction effort will increase the number of effective projects being generated. With Sikorsky acquisition of PZL as well as future acquisitions, the amount of UTC human and intellectual capital is astonishing. Unfortunately, there is little awareness of M28 program within the Sikorsky organization. At PZL, Sikorsky employees are only beginning to become acquainted with the program. However, those who are aware of the program are extremely impressed by the product. It has superb performance capability



that excites aviation engineers. It provides lucrative business expansion opportunity for Sikorsky. The first step is to raise awareness among the upper managements of various subsidiaries. The role of PZL upper management is to promote product awareness, especially outside of the PZL organization. A significant progress has been made in this arena. The second step is to raise awareness in mid-management and on the factory floor. Advertising through company publications can play an introductory role. Management rotational program will introduce mid-level manager to the product. Exchange programs including joint Kaizen events will help to build collaborations between technicians on the factory floor. Holding annual supplier meetings at PZL will not only introduce Sikorsky supply chain experts to the program, but also raise awareness among key Sikorsky suppliers. Such cross-site exchanges have been implemented with the BLACK HAWK program at PZL. Implementing similar events but centers around the M28 program is critical for raising product awareness. Raising product awareness is a critical theme that will be repeated in the remaining chapters

- **Drive relationship building.** Upper and mid-management should also drive relationship building throughout all ranks of the organization. One critical limiting factor of cost reduction is the competition of manufacturing resources with the Sikorsky BLACK HAWK program at PZL. A change agent with network both at Sikorsky and PZL will have enormous resource negotiation leverage. Many procurement-related activities will also require close interaction with Sikorsky parent company. Forming cross-subsidiaries supplier long term agreement (LTA) will also require relationship at the mid-management levels. Furthermore, many PZL components, including engines, are

purchased from other UTC subsidiaries. A change agent who understands inter-organizational dynamics will be able to generate explosive amounts of transfer-pricing related projects

- **Solicit customers input.** Most importantly, M28 is designed to satisfy customer's needs. Customers who have access to wide variety of products may provide recommendations based on competitors product on reducing cost. Furthermore, given the inelasticity of the defense industry, the customer is often willing to pay a premium for highly-needed features. Consequently, they are critical for the cost reduction and pricing efforts

#### 4.4 Concept collection database

A framework that links the bottom-up generated project list with the top-down M28 cost structure will be presented here.

First, a concept collection database is created based on the recommendations provided by the previous chapter. Projects are collected from the design, manufacturing and procurement organizations and are input into the database through a bottom-up process. After that, formal metrics are implemented in the database to evaluate, prioritize and track individual projects. A prototype of this database has been developed.

The database essentially replaces the project management system of the individual departments. In order to ensure the participations of various functional groups in the creation of such database, the database must satisfy the criteria that are important to tool adoptions as outlined in an earlier chapter. The author, also the prototype developer takes the following actions to address these concerns:

- **Value.** The tool needs to provide significant value to end-user in order to justify the associated switching cost. To do so, the deficiencies of current approach, including a lack of stringent metrics requirement that drive cost reduction are highlighted to management to show the need for change. To promote the new tool, the change agent should underline the additional graphics that simplifies data analysis and improve user experience. Listening to the voice of the customer is also critical in guaranteeing a value-added product. During metrics definition phase, the tool developer collaborates closely with end-user in soliciting relevant metrics. Missing metrics are added based on the user's recommendations, and unnecessary ones are removed accordingly to reduce product complexity. A period of test phase involving revisions base on user-feedback occurs before the final product roll out. Such interaction helps to ensure a database that provides value, as well as converting users to become champions for the tool
- **Credibility.** As the developer of the tool, the author of this thesis has to build personal credibility in order to maximize tool adoption. First, he has to achieve quick wins in areas unrelated to the tool development. This involves connecting relevant decision-makers that enable PT6A engine cost reduction. Second, he has to seek a champion who is willing to try the tool. Additional eye-pleasing graphics capability acts as a major selling point. For the less-willing late adaptors, the developer needs to build up credibility through other minor but relevant quick wins, including data entry, physical labors, and providing relationship networks critical to their successes. Most importantly, the developer needs to emphasize that the tool will not threaten job securities. The success of the tool should be credited to the user as a partner in tool development, not

the leading developer of the tool. During the development of the prototype, the author of this thesis follows the same reasoning to build credibility in the procurement organization

- **User-friendliness.** Unlike research findings outlined in the previous chapter, user-friendliness is critical to this new tool adoption. The main obstacles and switching cost for adopting the new tools are threefold. First, significant time and labor resource will be needed to transfer project proposals from current to the new tool. Second, different sets of metrics are used by different organizations, potentially forcing the user to interact with metrics irrelevant to his organization. Third, the new tool may have radically different user-interface, requiring significant resource for tool adoption. To resolve these concerns during prototype development, the developer and the author of this thesis took on the responsibility of data transfer. To minimize work interruption, the transfer occurs only during off-work hours on the weeknights and weekends. While the database incorporates metrics used by all organizations, a one-button excel macro is implemented, such that metrics relevant to a single organization could be displayed selectively. To reduce learning curve, the basic GUI is identical to those of the original tools. Lastly, all instructions and tool heading are bilingual, with English and Polish language options
- **Documentation and training.** The instruction for the tool is written in English as well as Polish. Providing tool training has become a priority for the developer, ready to offer step-by-step on demand

- **Transparency.** The key objective for the centralized concept collection database is to increase accountabilities for cost reduction efforts by promoting cross-departmental transparency. Currently, with unclear ownership assignments, many key projects lose traction and fail to obtain resource needed to achieve success. On the other hand, projects with insignificant cost-reduction potentials are draining limited resources. The database needs to be located at a centralized server, with equal access by all stakeholders. Doing so ensure that the individual department's work is evaluated by its peer
- **Database ownership.** As the database becomes an integral part of M28 cost reduction, it will continue to improve organically with the support of key stakeholders. A member of the Optimization Team is assigned to continue supporting the tool development

Metrics are designed for manufacturing and procurement groups, the two key organizations in the cost reduction effort. Unfortunately, the two group leaders currently use radically different metrics for project tracking. Procurement organization uses the gated work transition management policy, and the manufacturing group leader uses a customized set of metrics to evaluate assembly progress. Furthermore, both organizations are unwilling, and rightfully so, to adopt a set of metrics too general for either organization. Consequently, while the database consolidates all project proposals, it is customizable through a single button, displaying different metrics based on user's individual preference.

The following metrics are used in the manufacturing organization interface of the database prototype (Figure 17). Given the large number of columns used, separate screenshots are taken on the left and right portion of the database.

- **Owners and status updates.** Each project is assigned a clear owner. A status update field documents the history of project progress. Start and complete date and progress meter tracks project progress. Since significant amount of projects end pre-maturely, a field, “Reason for Terminations” is added to aid failure analysis. The notations are:
  - K - Completed
  - M – Production issue, lack equipment required to manufacture parts
  - P - Design constraint, require radical design change
  - D - No external supplier available with the required manufacturing capability
  - J - Poor quality of replacement parts
  - Z - Lack resource required to complete project
  - F - Project cancelled due to failure to meet financial goal
  - S - Project cancelled due to change in business strategy
- **Labor hour related parameters.** Labor hour metrics are divided among three groups: setup time ( $t_{pz}$ ), work time ( $t_j$ ), and total labor hour. Within each group, labor hour before and after project implementation, and potential labor hour savings are documented
- **Cost parameters.** The financial saving of each projects are tracked using three fields: cost before projects, target saving and actual cost saving (latest estimate). These fields are critical for prioritizing projects. While it is common for initial saving estimate to

deviate from actual saving, the two fields are critical in understanding the accuracy of cost forecasting. The discrepancy between the two must be minimized to insure resources are allocated to the more critical projects

The following metrics are used in the procurement organization interface of the database prototype (Figure 18).

- **Owners and status updates.** Same as those for manufacturing organization. Since procurement department head is interested in tracking projects in addition to those pertaining to the M28 program, a separate field is added to notate the different programs. An additional procurement objective is to reduce logistics complexity by minimizing the number of distinct part numbers. A field is added according to track part numbers. These are examples in which satisfying the need of end-user helps to expedite tool adoption
- **Gated process related parameters.** Procurement department uses a gate process based on UTC Operations Work Transition Management Policy. The metrics track completion date for each gate, as well as aggregated saving for each fiscal year
- **Cost parameters.** Same parameters used in the manufacturing organization

Additional features are provided in the procurement interface. A set of continuously updated summary charts are implemented. One chart tracks the number of projects completed according to target (Figure 19). Another chart displays the number of project completed, the value of the project, number of associated distinct part numbers, and total saving at each gate (Figure 20).

M28 BAZA DANYCH KONCEPCJI OPTYZMALIZACJI  
M28 OPTIMIZATION CONCEPT COLLECTION DATABASE (move cursor to A1 to see instructions)

Zobacz Opcje:

Lp.	Projekt/Działanie	Stan Aktualizacji (w Tym Daty)	Osoba Odpowiedzialna	Początek (mm/dd/yyyy)	Termin Realizacji (mm/dd/yyyy)	Produkcja, Projektowanie, lub Zakupu (A. Straz) (M/P/Z)	Realizacji (%)	Powód Zakonczenia (K/M/P/D/J/Z/F/S)	Wyjściowe Godziny Pracy (t <sub>pr</sub> )
Item	Project/Action	Status Updates (include Dates)	Owner	Start Date (mm/dd/yyyy)	Completion Date (mm/dd/yyyy)	Production, Design or Procurement (A. Straz) (M/P/Z)	Progress Meter (%)	Reason for Termination (K/M/P/D/J/Z/F/S)	Labor Hours Before Project (t <sub>pr</sub> )
1	Części o największej pracochłonności i najdłuższym LT - propozycja i realizacja każdej pozycji		Włodzimierz Adamski	1/6/2010	15/7/2010	M	15		
2	Części o największej pracochłonności i najdłuższym LT - propozycja i realizacja każdej pozycji		Arkadiusz Węgrzyn	1/6/2010	15/7/2010	M	60		
3	Maty wyguszające - ocena zastosowania		Tomecki Wiesław	14/6/2010		M	0		

80

Wyjściowe Godziny Pracy (t <sub>pr</sub> )	Godziny Pracy Docelowe Oszczędności (t <sub>pr</sub> )	Godziny Pracy Oszczędności L.E. (t <sub>pr</sub> )	Wyjściowe Godziny Pracy (t <sub>i</sub> )	Godziny Pracy Docelowe Oszczędności (t <sub>i</sub> )	Godziny Pracy Oszczędności L.E. (t <sub>i</sub> )	Wyjściowe Godziny Pracy	Godziny Pracy Docelowe Oszczędności	Godziny Pracy Oszczędności L.E.	Koszty Początkowe (PLN)	Wskaźnik Oszczędności (PLN)	Rzeczywiste Oszczędności L.E. (PLN)	Uwagi
Labor Hours Before Project (t <sub>pr</sub> )	Target Labor Hours Saving (t <sub>pr</sub> )	Labor Hours Saving L.E. (t <sub>pr</sub> )	Labor Hours Before Project (t <sub>i</sub> )	Target Labor Hours Saving (t <sub>i</sub> )	Labor Hours L.E. Saving (t <sub>i</sub> )	Labor Hours Before Project	Target Labor Hours Saving	Labor Hours Saving L.E.	Cost Before Project (PLN)	Target Saving (PLN)	Actual Cost Saving L.E. (PLN)	Comment
												Ile jest starych mat po wyczerpaniu
												wprowadzamy, rozeznac podobne przykłady 28.a

Figure 17: Manufacturing organization interface



M28 BAZA DANYCH KONCEPCJI OPTYZMALIZACJI  
M28 OPTIMIZATION CONCEPT COLLECTION DATABASE (move cursor to A1 to see instructions)

Zobacz Opcje:

Wszystko	M28	Opt. (Kokoszka)	Zakupy (Straż)
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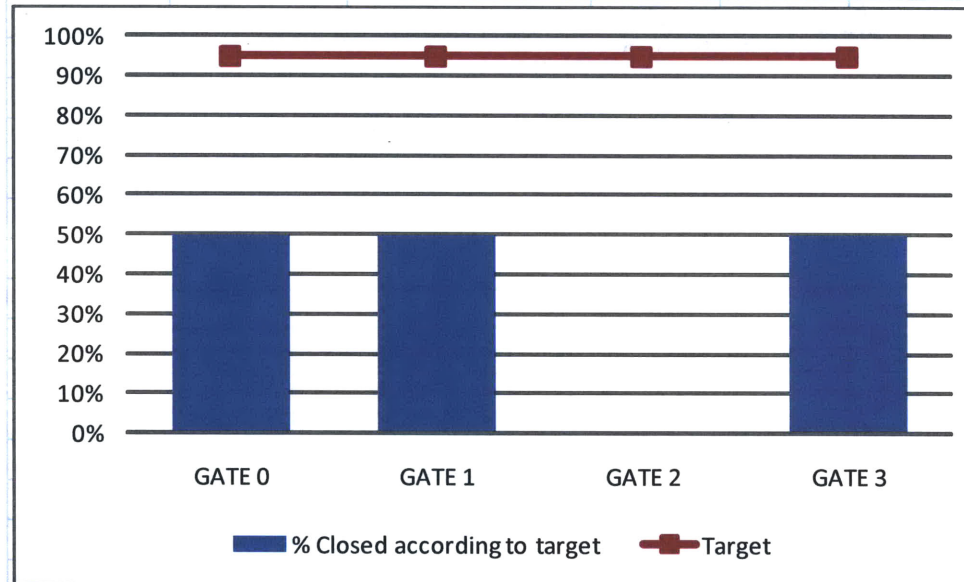
Lp.	Projekt/Działanie	Stan Aktualizacji (w Tym Daty)	Status (b/b, m/b, new)	Osoba Odpowiedzialna	Początek (mm/dd/yyyy)	Termin Realizacji (mm/dd/yyyy)	Program	Produkcja, Projektowanie, lub Zakupu (A. Straż) (M/P/Z)	Realizacji (%)	Powód Zakonczenia (K/M/P/D/J/Z/F/S)
Item	Project/Action	Status Updates (include Dates)	Status (b/b, m/b, new)	Owner	Start Date (mm/dd/yyyy)	Completion Date (mm/dd/yyyy)	Program	Production, Design or Procurement (A. Straz) (M/P/Z)	Progress Meter (%)	Reason for Termination (K/M/P/D/J/Z/F/S)
1	Seats frame M28 - outsourcing		m/b	A. Tabor		28/1/2010	M28	Z	100	K
2	Nakładanie Maskanta		m/b	A. Straż		28/9/2009	M28	Z	100	K
3	Fittigs, buy parts - zmiana dostawcy		new	A. Straż		28/9/2009	TC/TRP	Z	90	
4	Outsourcing Nitów - outsourcing		m/b	A. Straż		28/5/2010	M28	Z	75	
5	Outsourcing śruby, nakrętki - outsourcing		m/b	A. Straż		28/5/2010	Cabin	Z	60	

81

No P/N	Status (Gate)	Gate 0	Gate 1	Gate 2	Gate 3	2010	2011	2012	2013	Koszty Początkowe (PLN)	Wskaźnik Oszczędności (PLN)	Rzeczywiste Oszczędności L.E. (PLN)	Uwagi
No P/N	Status (Gate)	Gate 0	Gate 1	Gate 2	Gate 3	2010	2011	2012	2013	Cost Before Project (PLN)	Target Saving (PLN)	Actual Cost Saving L.E. (PLN)	Comment
5	GATE 5	Q3.2009	Q4.2009	Q4.2009	01.2010	160.00	400.00	400.00	400.00	80,000	20,000	20,000	Zatwierdzony dostawca STEMAR
286	GATE 5	Q3/2009	Q3/2009	Q3/2009	Q3/2009	-	-	-	-	33,880	0	0	
19	GATE 4	Q3/2009	Q3/2009	Q3/2009	Q3/2009	-	-	-	-	36,964	0	0	FAI approved
458	GATE 3	Q1/2009	Q2/2009	Q3/2009	Q2/2010					4,800	1,200	1,200	Dostawca Euro-Mag - wdrażanie wg zapotrzebowania
703	GATE 3	Q1/2009	Q2/2009	Q3/2009	Q2/2010					22,000	5,500	5,500	Dostawca WSK Tomaszów, Euromag - wdrażanie wg zapotrzebowania

Figure 18: Procurement organization interface

Gate	Number Gate Closed	Number of Gates Not Closed	% Closed according to target	Target
GATE 0	1	1	50%	95%
GATE 1	1	1	50%	95%
GATE 2	0	1	0%	95%
GATE 3	1	1	50%	95%



**Figure 19: Status of percentage of procurement projects completed according target**

Gate	Projects [No]	Savings [PLN]	Gate Value	
			P/N	[PLN]
GATE 0	7	457,956	987	4,292,652
GATE 1	17	159,216	738	1,571,233
GATE 2	6	83,568	252	270,050
GATE 3	7	12,133	1,720	67,131
GATE 4	4	14,116	74	404,066
GATE 5	2	20,000	291	113,880

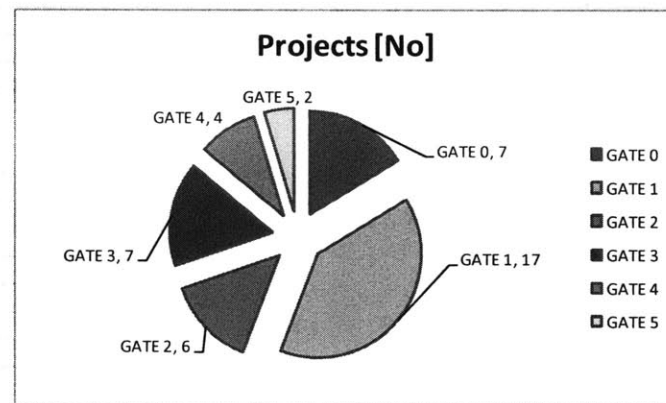
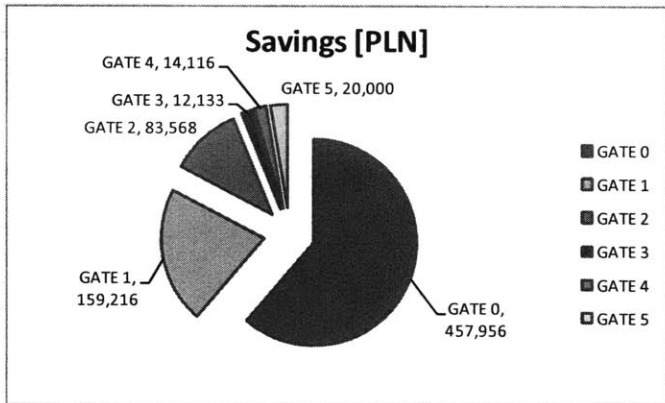
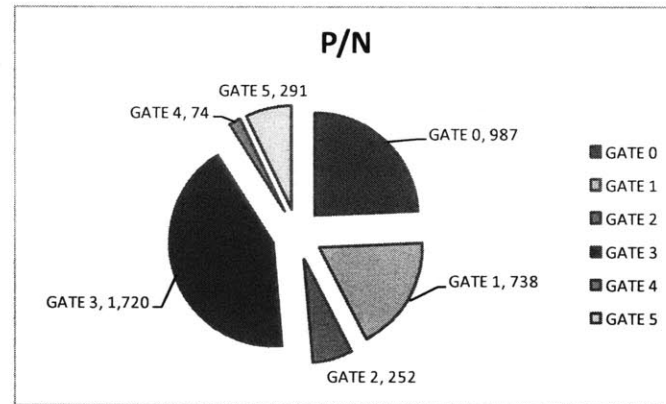
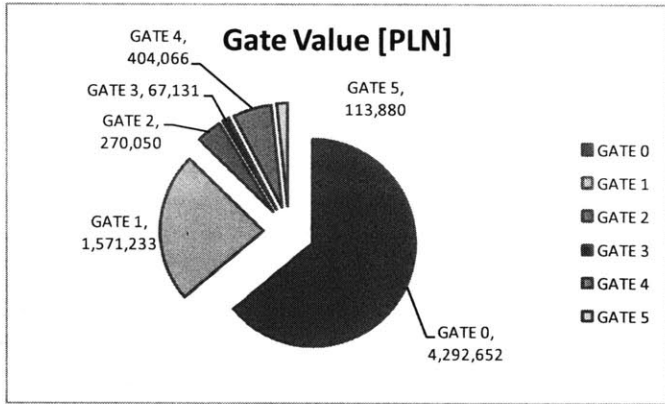


Figure 20: Status update of procurement projects savings

In addition to the two interfaces, the database also offers two charts that actively track total labor and cost reduction (Figure 21 and Figure 22). They are used by the Optimization Team to monitor the status of overall cost reduction efforts.

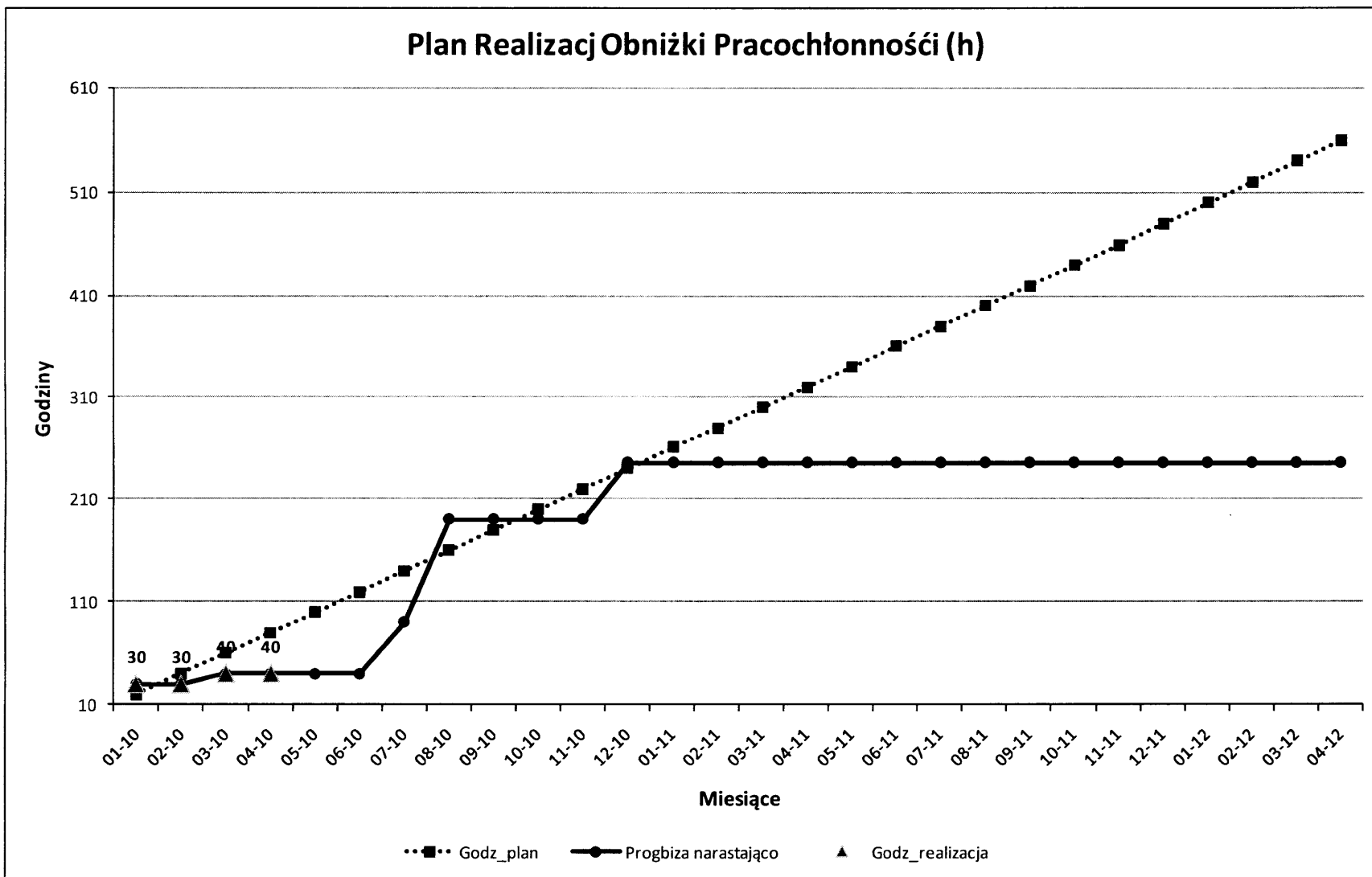


Figure 21: M28 labor hour reduction; square: target over 28 months; circle: achievable with current projects; triangle: actual savings

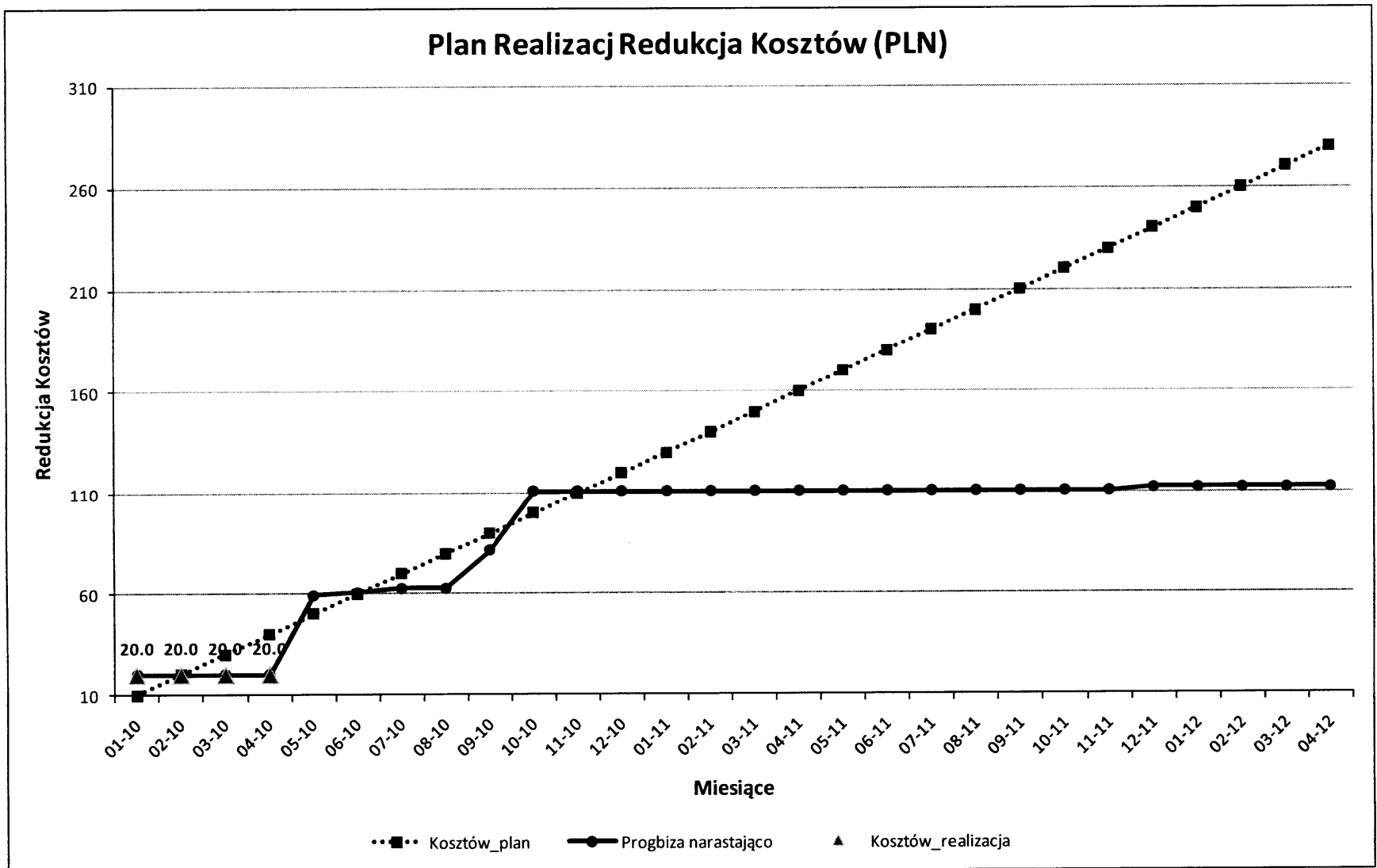


Figure 22: M28 cost reduction; square: target over 28 months; circle: achievable with current projects; triangle: actual savings

## 4.5 Summary and recommendations

In summary, a three-part project prioritization process is described in this chapter. A top-down analysis of M28's cost structure is first presented. Its labor cost is benchmarked against competitors. It is not feasible to relocate labor force to other geographical location to reduce labor rate. On the other hand, increasing batch size and reforming craft production could reduce total labor hour.

The material cost of the two most expensive components, the power plant and avionics are benchmarked against competitors. Collaborating with UTC sister division Pratt and Whitney could help PZL to obtain market engine rate and greatly reduce cost. Using bundling solution could help PZL reduce total avionics cost.

A set of recommendations aimed at streamlining bottom-up project generation is also presented. PZL should focus on:

- Drive project generation and resource allocation in maximum cost saving activities
- Implement systematic cost-reduction approaches as describe in Chapter 5, 6 and 7
- Promote innovative thinking
- Raise product awareness
- Drive relationship building
- Solicit customer input

By using the top-down M28 cost structure analysis as guidance, cost reduction projects should be generated by focusing on high-value components.

Lastly, a centralized project collection database prototype has been developed. With a list of project proposals inputted, their financial impacts are evaluated based on a simple set of cost-based rules. Only projects with significant impacts should be executed. For active projects, clearly defined ownership is critical to ensure project completion. Furthermore, sufficient resources need to be dedicated on critical projects. When necessary, the responsibility of the project execution needs to be elevated to senior management level.

The current culture at PZL also needs to be changed. First, increasing transparency is not only critical to M28 cost reduction effort, but also to the growth of PZL and Sikorsky. Unfortunately, driving transparency is difficult at PZL, a company that is undergoing transition from a former socialist economy structure. Fear exists throughout the organization that the tool will be used as a performance evaluation, and that a failure to reduce cost will translate to reductions in salary compensation. To resolve these concerns, upper management should initially separate the cost reduction results from individual performance evaluation. Over time, management should use the tool for performance evaluation with care. Failures due to factors unrelated to the project owner should be noted and compensated accordingly.

Second, the management needs to cultivate cost-focused mindset. Under such mindset, the workforce should focus on market cost requirement just as much as it has been focusing on engineering requirements such as payloads. In fact, cost target should be input to design, not output. Finance should play a leadership role in providing objective project valuations. In engineering, employees should realize that cost target is input to design, not output. To convince engineers the value of cost orientation, leadership should emphasize success will



enable more aircraft sales, while in turn will provide engineering with needed additional resources. Visuals should also be developed to function as behavioral trigger, and point to destination. Tools such as cost-reduction Andon board on factory floor and cost Meter at meetings (and in offices) tracking progress toward the 28% goal should be utilized.

By assigning resources to the most effective cost reduction efforts, the goal of 28% cost reduction over 28 months may be realized.

## **Chapter 5. AUTOMATION IN MANUFACTURING ORGANIZATION**

Chapter 4 describes a process that prioritizes projects, therefore effectively allocates limited resources among the different organizations at PZL. The following three chapters introduce detailed cost reduction concepts used in the three organizations. Chapter 5 presents automation as a technique used in the manufacturing organization for labor cost reduction. The concept is explained using nacelle deflection cover as a case study. As illustrated by the following sections, the current M28 manufacturing process is highly labor intensive as the aircraft is built in a prototypical manner. Consequently, significant labor cost reduction opportunities exist through the use of automation.

### **5.1 Case study: nacelle deflection cover**

A nacelle is a cover housing structure separated from fuselage that holds the aircraft's engine as well as its associated fueling systems. In the M28 cost categorization, it is grouped under the M28's power-plant subsystem. As illustrated in previous chapter, the power plant contributes the largest percentage of the total material cost. While it has less impact on labor cost, nacelle production is the most manually intensive among all aircraft components, therefore has the highest potential for labor cost reduction. Boeing and Airbus have incorporated automation using CNC equipments into their production process to improve manufacturing efficiency. This case study demonstrates M28 cost reduction using similar techniques.

### 5.1.1 Nacelle design requirement

The nacelle structure is designed to provide mechanical support and protection for the engine. It is also critical to engine performance. Each engine has unique aerodynamic as well as fire and safety requirements. The outer curvature of the cowl nose must be designed to avoid excessive local velocities in high speed flight. The inner contour not only must fit engine's dimension, but also need to accommodate thrust rating. It also needs to provide adequate spacing for electrical wiring, ducting and engine inlet systems. Consequently, a nacelle's design is mainly dictated by the engine chosen for an aircraft.

During early years of the program, the Russian turboprop TWD-10B was selected as the engine of choice for M28. It is rated 947 shp, and works with the Hartzell HC-B5MP-3D five-blade 2.82m propeller.(Jane's Information Group) It weights 225 kg, and is 2060 mm long, 555mm wide and 900 mm high. At that time, the Russian engine designer worked closely with PZL in designing an optimal nacelle structure. Up to this day, this engine continues to power 13 M28 Bryzas of the Polish Navy and 10 M28B-1 TD STOL utility transport aircraft of the Polish Air Force. However, the TWD-10B production ended in 2007, when PZL decided to replace all engines of subsequent M28 production with Pratt & Whitney Canada (PWC)'s PT6A-65B.

The PT6A-65B engine, part of the renowned PT6A family, is rated at 1173 shp at 1700 rpm at 38.3 °C, and integrates with Hartzell five-blade reversing propellers.(Jane's Information Group) It weights 218 kg, with diameter 483 mm and length of 1880 mm. It is the engine of choice for the Thrush Turbo Thrush Commander A2RT-65, the Shorts 360, as well as the PZL M28 aircraft. When the engine was first chosen for M28, the nacelle was completely

redesigned to account for the increased horsepower, altered dimension and differences in fire suppression requirement. At that time, PWC only provided the aerodynamic balancing and general external shape requirements for nacelle structure. The complete redesign, including interior contour, was completed independently by PZL engineers.

### **5.1.2 Nacelle structure overview**

The engine nacelle consists of separate cowlings encompassing the PT6A-65B engines with associated systems and accessories. The nacelles are attached to the wings and load-carry-through frame on the engine mount. Due to their streamlined contour, they reduce aerodynamic drag and protect the engine and its system against adverse atmospheric conditions. The engine compartment is separated from the wing by a firewall.

The complete M28's engine nacelle consists of six major subassemblies: upper deflectable cowling, lower deflectable cowling, upper cowling panel, rear cowling part, left-hand (LH) and right-hand (RH) deflection covers, and firewalls (Figure 23). Including fasteners, the entire nacelle structure has over three thousand parts.

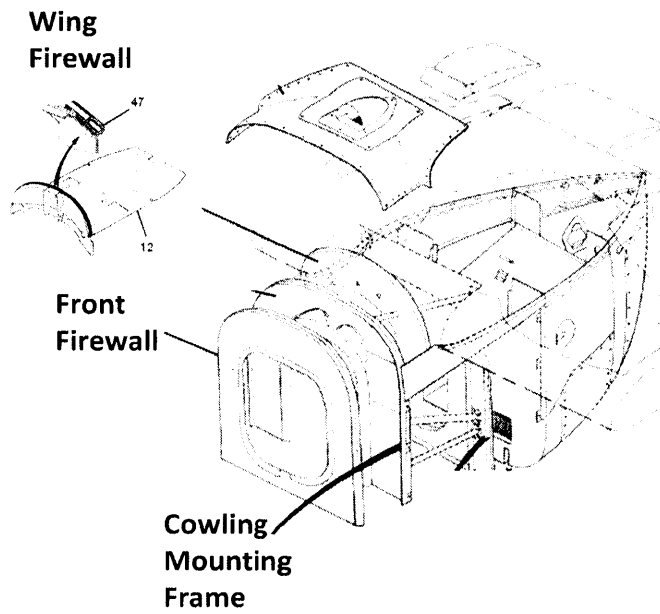
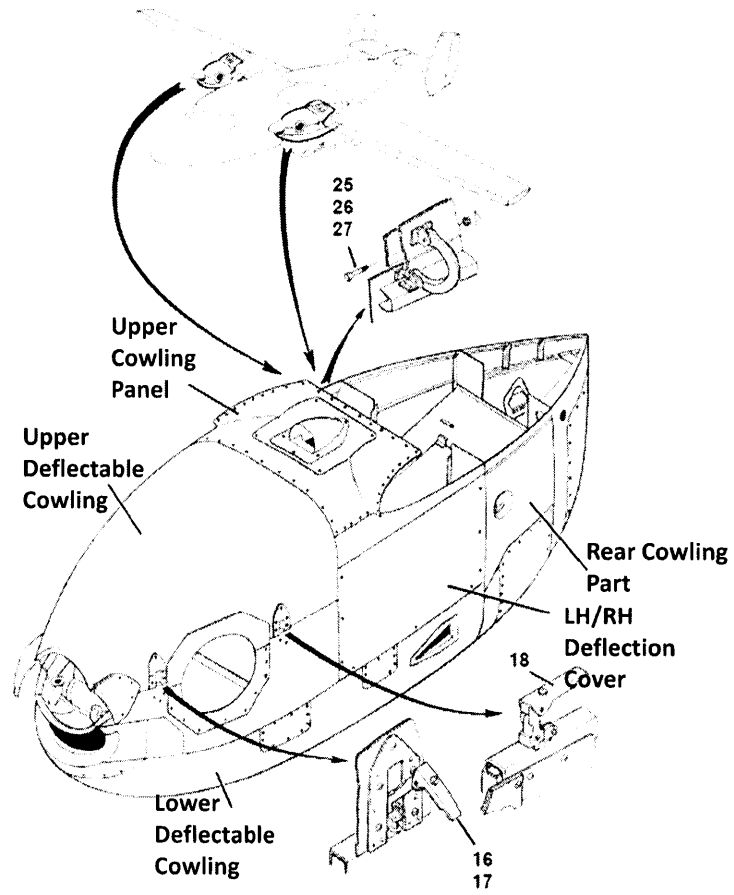


Figure 23: M28 engine nacelle structure

The upper cowling is a removable profiled fairing. On other side of the cowling, there are cut-outs for engine exhaust stack. It is closed with four quick-disconnect locks located on the lower edge of the cowling.

The four side deflection covers are attached with two hinges mounted in the upper part of the covers (Figure 24). In the open position, the cover is locked with a support structure. The cover in the closed position is secured to the frame and wall with nine quick-disconnect locks. A ventilation grate is riveted onto the cover's mid-section.

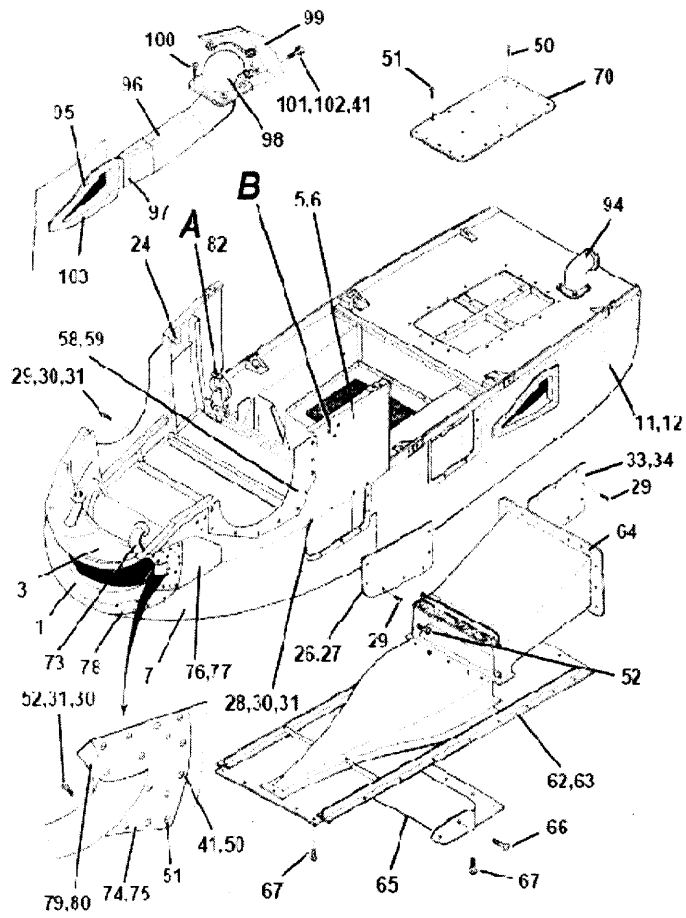
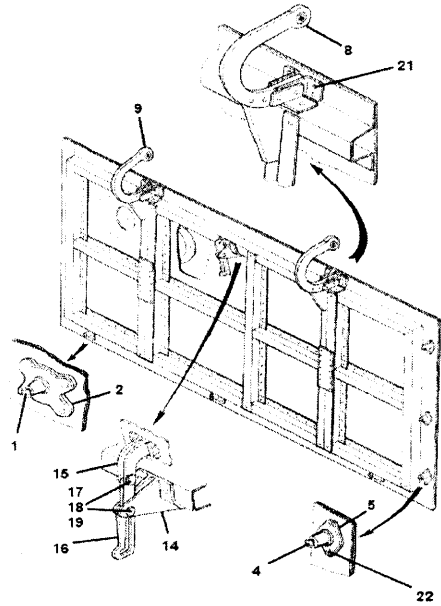


Figure 24: Top: M28 engine nacelle deflection cover; bottom: lower cowling

The lower cowling (Figure 24) is the core component of the nacelle structure. In fact, the assembly of nacelle begins with this cowling component. The engine mount and rear part of the engine cowling are fastened to the lower cowling. This structure also has a horizontal firewall and control limit cables. In the bottom, there is an inlet to the cooler and the starter-generator cooling duct. The air duct has a by-pass bifurcated line equipped with steerable shutters. The air duct channels air to the oil cooler. After passing through the oil cooler and absorb heat, the air is expelled outside via holes in the rear fairing of the nacelle. The air duct nose skin is made of stainless metal sheet. The nose is heated with the exhaust gases leaving the exhaust stacks. A water drainage system is also connected at the bottom of lower cowling to carry away accumulated operating liquid and water.

The upper panel is attached to the structure using anchor nuts and screws. In the central part, there is an inspection hole with a ventilation system air intake.

The rear cowling is a fixed element of the nacelle fastened to the wing. The oil cooler, its duct, and the fire extinguisher are located in the rear part of the nacelle. Both the oil cooler and the fire extinguisher are separated from the engine by a firewall.

The firewall structures consist of wing firewall and front firewall. The wing firewall is a stainless steel component located near the upper panel that separates nacelle from the wing. The M28's fuel tank is located in the wing, so consequently, this wing firewall is critical in protecting the wing and the fuel tank from overheating. The front firewall functions as a fixture near the engine turbine section and provides additional fire protection.



### 5.1.3 Current manufacturing process

Currently, the nacelle structure is produced based on the original prototype designed immediately following the PT 6A replacement. Such craft production process relies heavily on manual labor. Without the production level needed to justify production process improvement, design and manufacturing have not been changed to support serial production. The two deflection covers, located on the two sides of nacelle, have the least structural complexities among all the sub-assemblies. Consequently, they are chosen for redesign-for-manufacturing using CNC machine, as a first attempt to transition towards serial production. The subsequent discussion will focus on the challenges of overall nacelle manufacturing process, while using deflection cover as example.

PZL Manufacturing is divided into five productions centers: special processing (P200), machining (P300), sheet metal (P400), sub-assembly (P500), and final assembly (P600). The labor hour distribution for nacelle production is described by Figure 25. P200 provides processing such as anodizing and chemical washing. Since P200 plays a supporting role to other production centers, its labor hour is grouped into P300 and P400 based on the location of the part's originality.

<b>Production Centers</b>	P300	P400	P500	P600	Total
<b>Functions</b>	Machining	Sheet Metal	Sub-assembly	Final Assembly	
<b>%</b>	10%	28%	49%	13%	100%

**Figure 25: Nacelle manufacturing labor hour breakdown: current state**

The Sheet Metal Center is responsible for shaping, cutting and stamping metal sheets to parts used for sub-assembly and further machining. Precision forming and shaping equipments are placed here. Special plastic and wood molds used for cutting and shaping are produced within PZL. Additional processes such as heat treatment are also done at P400. The Machining Center (P300) has been partially used to manufacture rivets and fasteners. It consists of basic machining equipments as well as CNC machines. Furthermore, many new types of equipment were purchased after Sikorsky acquisitions. The production center is playing an increasingly important role in the transition to automation. After P300 and P400, the five nacelle components are individually assembled in sub-assembly center (P500). They are also joined together and installed onto the aircraft at the final assembly center (P600) with the engines.

Specifically, the nacelle sub-assembly process flow is shown in Figure 26. In Poland, 21 labor days is used for production scheduling. The labor hour recorded for cost accounting discounts idling, drying or transportation time. The production days recorded, on the other hand, includes these additional times.

The assembly process begins by assembling the engine air duct and air duct inlets, components of the starter-generator and oil cooler's ventilation and cooling system. The air duct inlet shutter blades, as well as the thermo regulator that controls them are assembled next. The cooling system and other components are then installed onto the main lower deflectable cowling structure. Following that the water drainage system is attached to the bottom of lower deflectable cowling. While the lower cowling structure is assembled, other

sub-assemblies, including the deflection cover and upper cowlings are assembled individually.

Lastly, the nacelle structure is installed onto the aircraft.

The deflection cover's current manufacturing process occurs throughout the four manufacturing centers, with the labor hour distribution shown below:

## Nacelle Sub-assembly Process (P500)

( in days, with 21 labor days/month)

100

	Days	Hours
Engine Air Duct	4	51
Engine Air Duct Inlet	2	22
Engine Air Duct Regulator	3	65
Engine Air Duct Blade	5	90
Lower Deflectable Cowling	20	325
Drainage System	1	23
Deflection Cover	8	30
Cowling Mounting Frame	1	9
Wing Firewall	3	68
Upper Cowling Panel	5	14
Upper Deflectable Cowling	4	150
Rear Cowling Part	5	192
Front Firewall	2	15
Installation on Aircraft (P600)	16	420
<b>Total</b>	<b>51</b>	<b>1472</b>

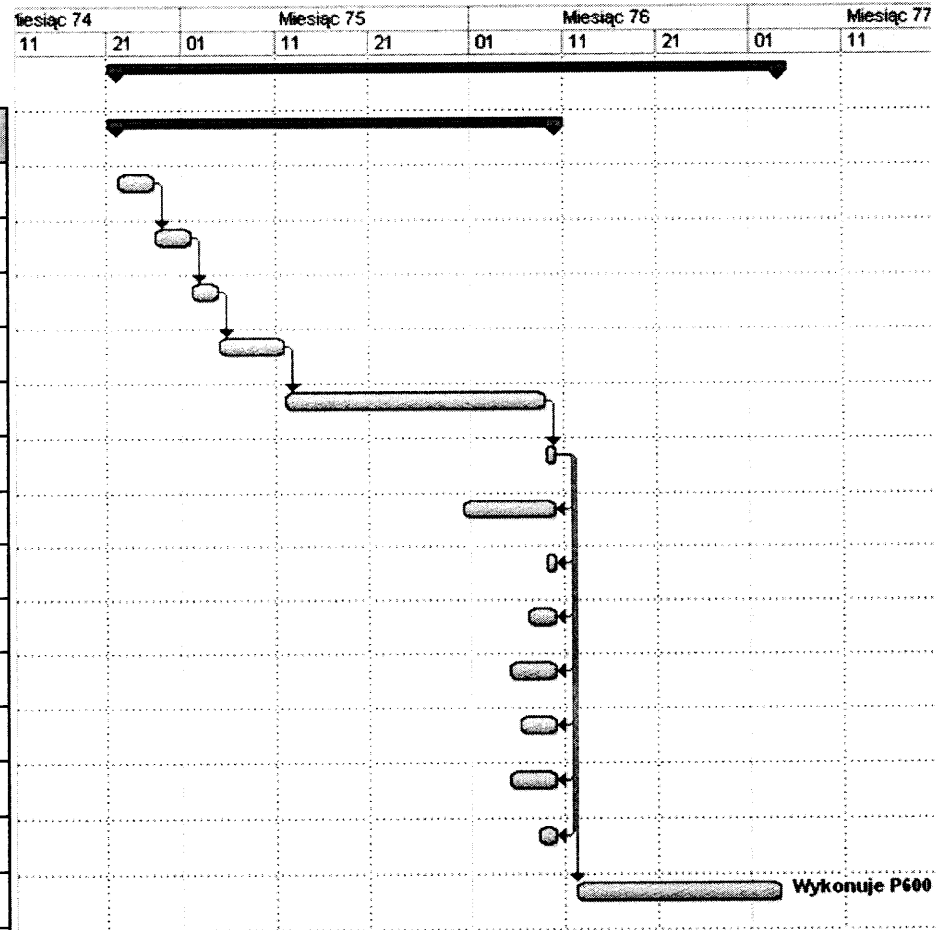


Figure 26: Nacelle sub-assembly process

The manufacturing flows for the main components are as follows:

- **Deflection cover skin.** The skin contributes the outer surface of the deflection cover. The skin is first cut from aluminum sheet metal in sheet metal center (P400) using a guillotine. It is then checked by quality control for material grade and geometry. The part is tagged with part description and job number, and the tag undergoes quality inspection. The metal sheet then undergoes degreasing and chemical washing. It is sent for heat treatment, and shaped using mechanical press and PZL-produced plastic mould. A technician inspects the part, and corrects any geometry discrepancies through manual filing and hammering. After additional tagging and quality check, it is sent to sub-assembly center (P500) to be combined with rib-structures
- **Rib structures.** The rib structures are used to provide structural reinforcement. Like cover skin, these structures are manufactured mainly at sheet metal center. Nine smaller pieces are first cut from aluminum sheet metal at P400 using a guillotine. They are checked by quality control for material grade and geometry. They are tagged and the tag information is checked again by QC. Their shapes are bent to “U” shapes using edge presses. The “U” shape structures are placed on a concave mold. A technician then manually hammers and bends the shapes into “Ω” forms. The technician also cut out excess materials as well as files away sharp edges. The structures then undergo degreasing and chemical washing. They are also heat treated and hardened. Since heat treatment could induce unwanted additional bending, a technician corrects the deformations, and sends the parts to QC and additional tagging. The structures are sent to P200 for chemical etching before being sent to P500 sub-assembly. At P500, the nine

rib structures are mounted onto the cover skin through welding. To setup the Sciaky electric welding machine, multiple witness samples are used for calibration. More than 300 spot welding points are used in the joining process. The jointed structure is sent to P200 for anodizing before a primer layer is applied for corrosion protection. The structure is then ready for mounting of the hinges

- **Hinges.** Hinges are used to mount the deflection covers onto the overall nacelle structure. An 80 mm x80 mm stainless steel metal block is first cut using guillotine in P400. It is then transferred to P300 after quality check. There, a technician flattens the metal block and removes 2 mm from the block edge using vertical milling machine. This process ensures evenness across the surface. After a technician pencils out the circular opening pattern located at the center of the hinge, a 9.5 mm diameter hole is drilled. The opening size is increased through milling process, so that it could be mounted inside a basic CNC machine. Unlike newly installed CNCs, the machine used for this operation has long processing time and only capable of simple operations. The inner surface of opening is then polished and mounted onto CNC. After the hinge shape is cut, it is dismantled, and the opening diameter is increased to 14 mm through additional milling. After additional polishing and quality checks, the hinge is sent to P500 and bolted onto the deflection cover
- **Ventilation grate.** The ventilation grate is a grating structure located at the center of deflection cover that improves air flow and engine dissipation. A stainless steel metal piece is first cut in P400 using a guillotine. After a quality check and tagging, a technician drills six 3 mm diameter holes onto the sheet metal. Three parallel lines are cut joining

two pairs of holes. The sheet metal is then reshaped using a manual press to form the grating pattern. After quality check and addition tagging, the part is sent to P500 and mounted onto the deflection cover

- **Quick-disconnect locks.** The locks are additional joints used to connect deflection cover with nacelle. They were previously produced at PZL, but are now purchased directly from suppliers

Manufacturing flows of these components are summarized in Figure 27 and Figure 28.

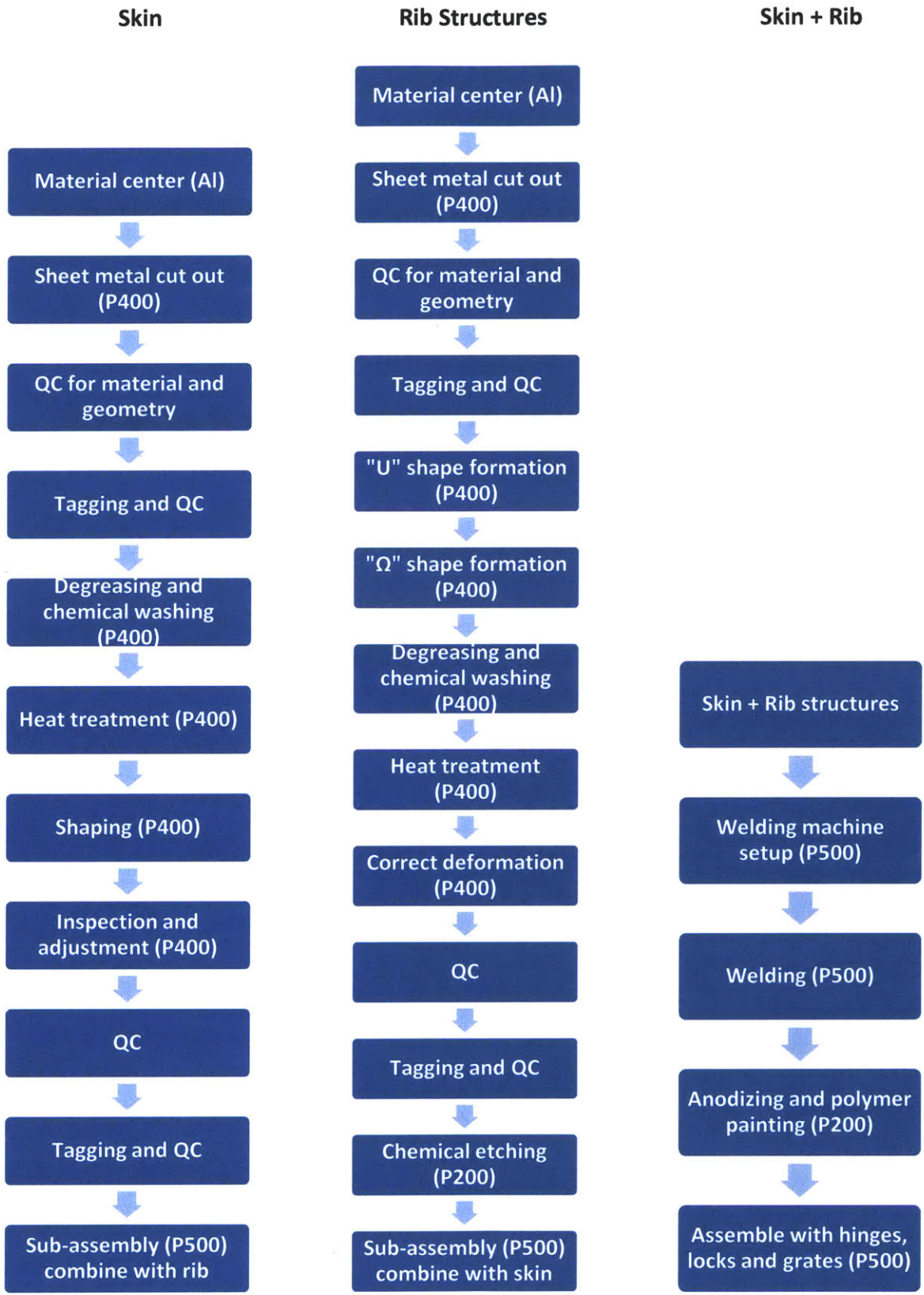
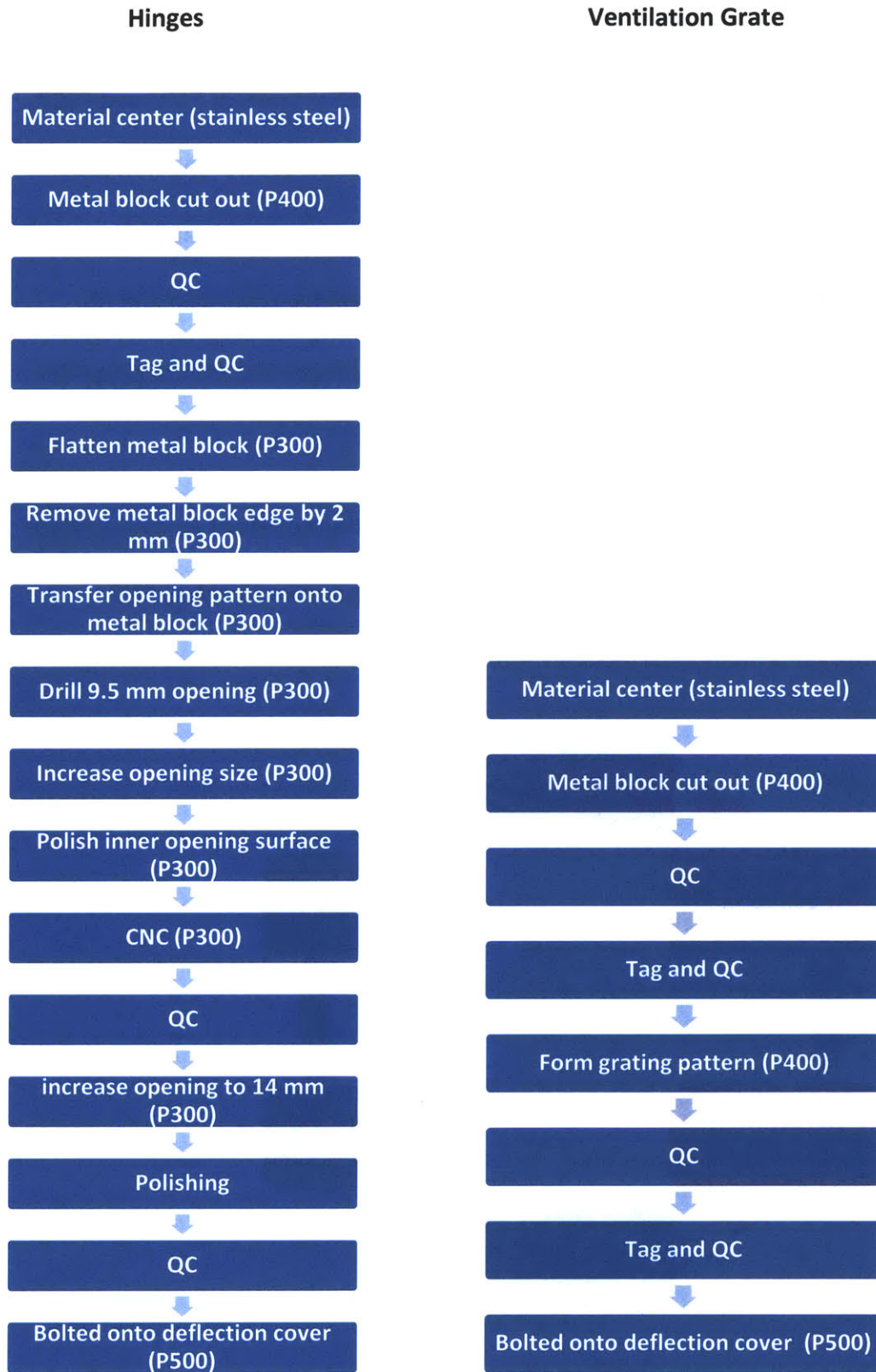


Figure 27: Original deflection cover manufacturing process: skin + rib structure





**Figure 28: Original deflection cover manufacturing process: hinges, ventilation grate**

#### 5.1.4 Deflection cover redesign process

The goal of automation is to reduce the manufacturing labor hours at P400 and P500, the most intensive among the four production centers for deflection covers. The new process described here is designed to reduce the labor hour needed for sub-assembly at P500, as well as shift production from P400 to P300. Specifically, it aims to combine cover skin and rib structure manufacturing into one simplified process. The locks, hinges and ventilation grates will still be mounted manually.

The deflection cover is first redesigned. The redesign cycle consists of six steps (Figure 29): Optimization Team sets redesign target, redesign, modeling and verification, CNC programming, Prototyping, additional modification.

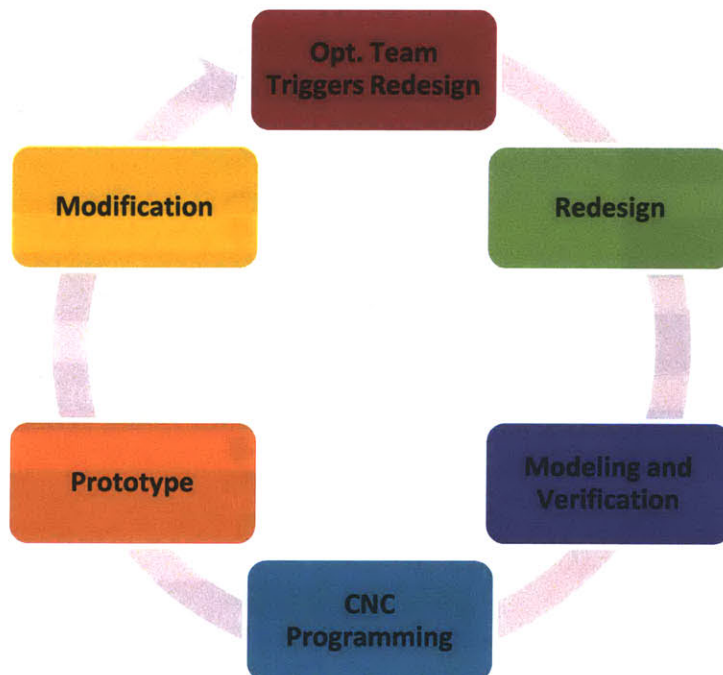


Figure 29: Deflection cover redesign cycle

The M28 Optimization Team first targets deflection cover as a test case for nacelle's redesign-for-manufacturing. It is chosen because of its low structural complexity. Unlike other cowling components, it has minimal curvature. With successful results, additional nacelle cowling structures will be redesigned for CNC manufacturing as well. The goal is to have a single-piece deflection cover.

Requirements are set at the beginning of the redesign process. To assist integration with rest of the nacelle structure, most design parameters are kept constant:

- Maintaining the same weight: to avoid increasing the weight of the aircraft, the structural mass is kept constant
- Maintaining the same strength requirement: the redesigned structure need to support the aerodynamic pressure as well as forces from other components of the system
- Using the same material: Russian grade aluminum D16AMW remains the material of choice
- Maintaining the same geometry

The geometry of the original deflection cover is imported from legacy DOS DAMS system and converted to 3-D model using CATIA modeling system.

The two main issues faced by designer are the cover skin thickness and rib structure thickness. A skin thickness of 0.8 mm is required in order to retain the same structural geometry. Unfortunately, PZL's CNC center does not have the manufacturing capability needed to support small feature sizes. Furthermore, small skin thickness increases plate deflection. As deflection angle continued to increase through the cutting process, the actual cover thickness

increasingly deviates from specification. Through modeling and sample runs, a skin thickness of 1.4mm is set. To compensate for the increase in skin weight, the rib weights are reduced accordingly.

The designer then replaces the welded  $\Omega$ -shape rib structures with solid rib structures. It is sent to calculation department for MSC NASTRAN modeling and numerical strength tests.

Accumulation pressure on the deflection cover was first determined. The deflection cover experienced a uniform aerodynamic suction pressure of  $0.0055 \text{ N/m}^2$  (Figure 30). One half of the deflection cover is in close proximity of the inner engine compartment. Because air is pumping into the compartment during engine operation pushing against deflection cover, one half of that experienced an additional  $0.00867 \text{ N/m}^2$  pressure. Additional stresses from hooks and locks were also calculated. The rib structure is modeled and sized to support these external stresses as well as its internal stress (Figure 31). With a maximum stress requirement of 200 MPa, the rib thickness varies from 1.4 to 3 mm along the deflection cover. Since the rib structure provides the main pressure support, the thickness of cover skin was irrelevant in the modeling.



Figure 30: Deflection cover pressure modeling

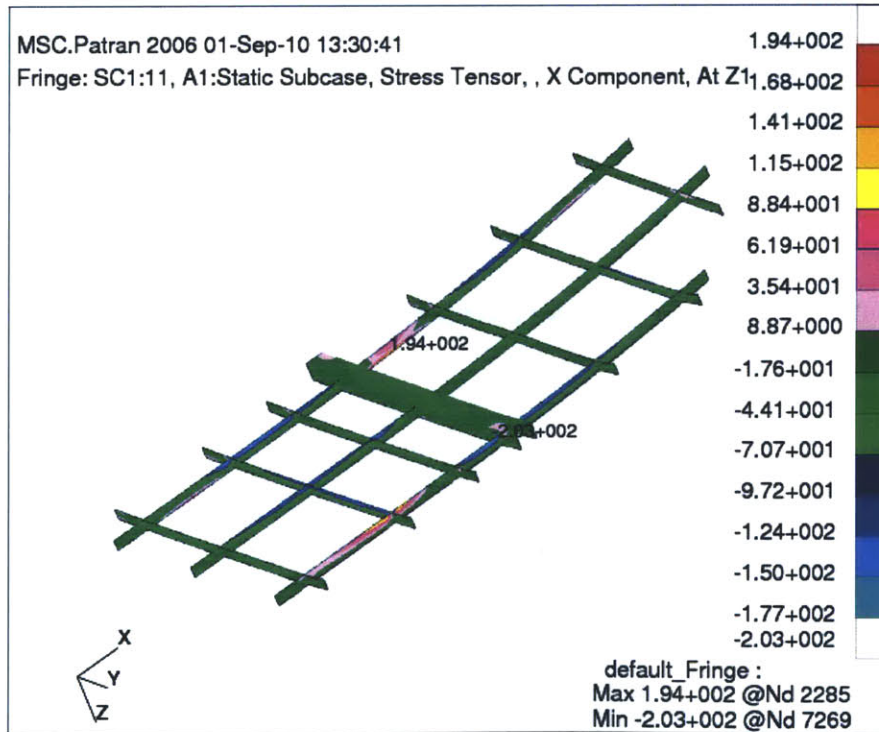
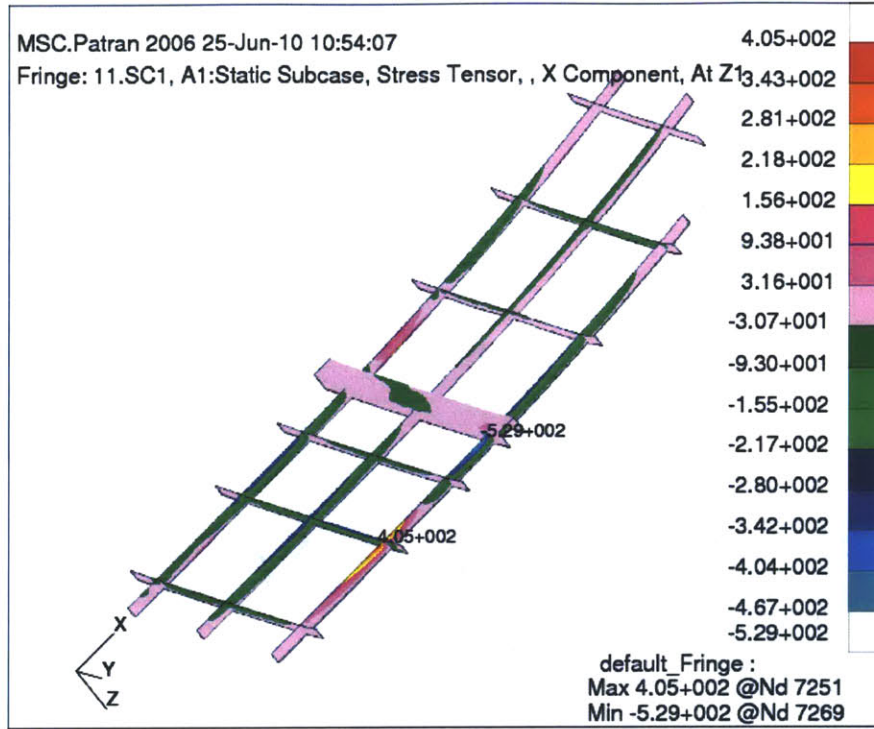


Figure 31: Rib thickness is varied from 1.4 to 3 mm along deflection cover to reduce internal stress; top: uniform thickness, bottom: varied thickness

With additional geometric parameters received from the calculation department, the designer finalizes the deflection cover structure and export to CNC programming department. After the machine code was written, a prototype was manufactured using a much simplified process described in Figure 32. Multiple production steps have been eliminated by combining cover skin and rib structure into a single manufacturing stream. To prevent unwanted bending during CNC process, a metal brick with large thickness is used. Since material cost is a key part of the overall component cost, the thickness will be greatly reduced in the future to minimize cost of scrap. The prototype (Figure 33) has been test-fitted onto the nacelle structure.

#### Cover skin + rib structure (New)

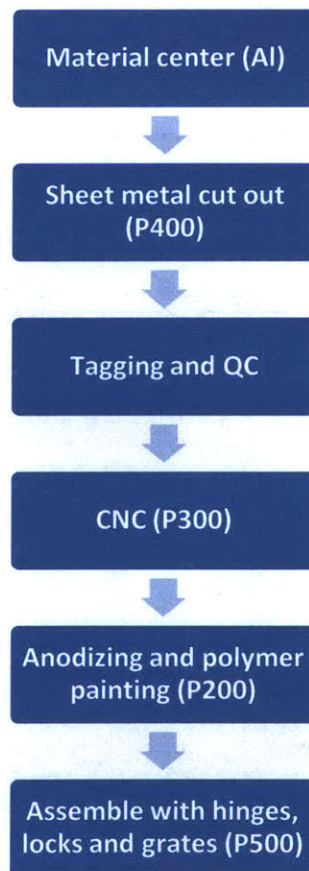
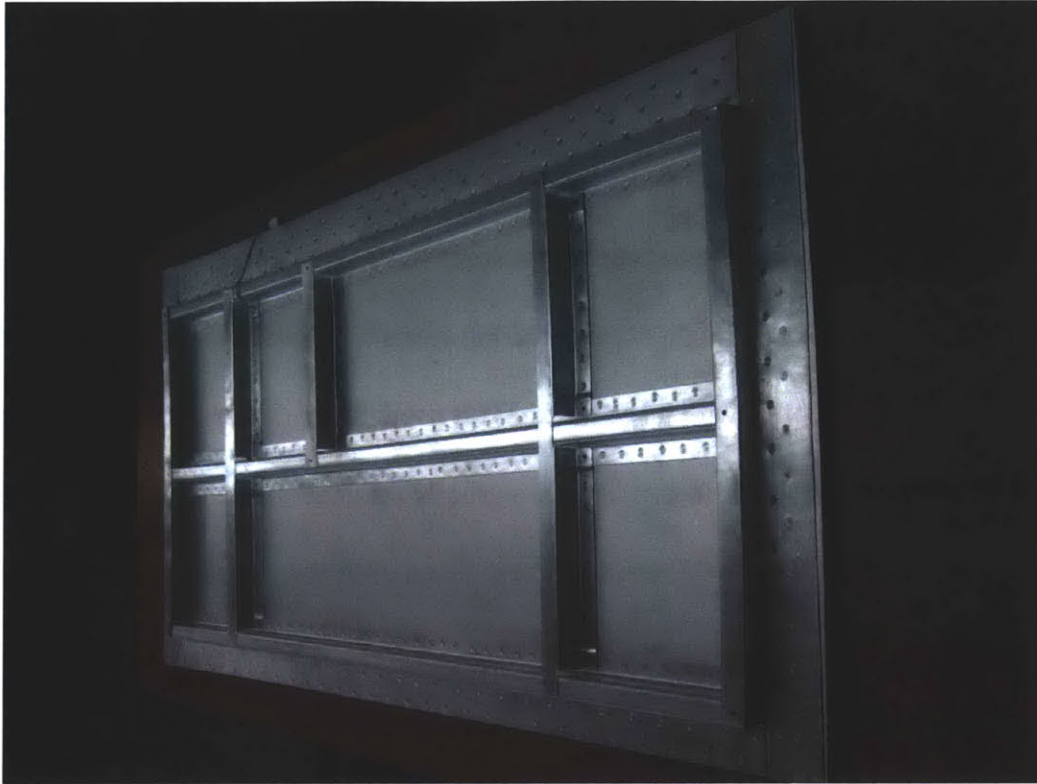


Figure 32: New deflection cover manufacturing process: skin + rib structure



**Figure 33: Top: original riveted deflection cover; bottom: CNC deflection cover**



The labor hours required to produce a single deflection cover using the old and the automated methods are shown in Figure 34. As expected, the labor hour is greatly reduced in P500 as less manual mounting of components are required. While there is small increase in labor hour in P300, there is greater deduction in the P400. P600 final assembly is not affected by this transition to automation. Overall, there is a net 2% decrease in the overall nacelle production's labor hour. It is greater than the sum of labor hour reduction at each center since originally there is more labor content at P400 and P500. While the change is small compare to the overall M28 cost structure, it is a starting point to overall automation effort.

<b>Production Centers</b>	P300	P400	P500	Total
<b>Functions</b>	Machining	Sheet Metal	Sub-assembly	
<b>Labor Hours (Original)</b>	8.7	32.3	30.9	71.9
<b>Labor Hours (CNC)</b>	17.1	11.1	5.0	33.3
<b>Labor Hour Change (%)</b>	97%	-66%	-84%	-54%
<b>Nacelle Labor Hour Change (%)</b>	4%	-3%	-2%	-2%

**Figure 34: Nacelle manufacturing labor hour breakdown: automated state**

With promising result from CNC deflection cover, similar approach will be applied to automate the manufacturing of other structures.

## 5.2 Summary and recommendations

This chapter illustrates the effectiveness of using automation to reduce nacelle manufacturing labor hour by 2%. However, the potential of automation is limited by two key factors. First, there are technical challenges associated with manufacturing large structures with curvature using CNC machines. For example, large nacelle structure such as lower cowling has been evaluated against PZL CNC capabilities. Due to size, geometry (e.g. curvature) and

material constraints, they could not be manufactured as single-piece using the equipment. The interior chamber of the largest CNC machine limits the size of the component being produced. The machine's capability also limits the ability to produce parts with large curvatures. As a component with minimal thickness and long shape is cut from the raw material, it curls and deflects from its original position. The amount of deflection also may vary across different copies of the same components. While it is possible to calibrate the equipment to account for the shape change, it is difficult to adjust for variability. A more advanced equipment with monitoring feedback mechanism can potential resolve this issue. On the other hand, the high capital investment cost may have insufficient ROI to justify the purchase of new equipment. This is especially true since most of the current CNC machines at PZL are obtained from Sikorsky US factory with minimal transfer cost. Regardless of the constraint, smaller sub-components will be evaluated in order to reduce labor cost through automated manufacturing process.

Second, M28 has to compete with BLACK HAWK, Sikorsky's core business for CNC resources. As mentioned in the earlier chapter, the initial goal of PZL acquisition is to expand production capacity for Sikorsky's existing BLACK HAWK program. While M28 is critical for PZL, it is less so for the parent company since its financial impact is minimal compare to Sikorsky's core business. The BLACK HAWK program always has priority in using design and manufacturing resources. In fact, M28 deflection cover could only be manufactured when there exists excess CNC capacity. The redesign for the deflection cover is relatively simple, and theoretically could be completed within two weeks. However, the job is constantly displaced by more critical BLACK HAWK assignments. For example, sub-components of the helicopter's cabin structure, due to strict tolerance requirement, are produced using CNC. As a result, the redesign cycle

took approximately five months to complete. As BLACK HAWK production continues to ramp up, CNC and design resource will become increasingly scarce.

To achieve more effective cost reduction through automation, PZL need to take the following actions:

- **Raise product awareness.** This has been described in Chapter 4
- **Dedicate automation champion.** There needs to be a dedicated change agent who drives redesign that enables automation. An influential champion is critical to ensure that projects are on-schedule. The agent could potentially be a former Sikorsky employee, as the past experience provides him with the relationship network needed to negotiate for resource with high-level decision makers
- **Develop long term plan.** A long-term plan needs to be developed to incorporate effective organizational change concepts. As outlined by Heath, to direct the Rider, the change agent will need to use deflection cover as a past success story to convince other decision makers. He will set concrete plans with detail timeline based on the redesign cycle outlined earlier in this section. A clear owner will be assigned and be held accountable for each task. To motivate Elephant, he could leverage on the intellectual curiosity already existed for this high performance aircraft. Being able to contribute to the modernization of a cutting-edge program will be an honor for any avionic engineer. There is genuine interest from BLACK HAWK engineers who are willing to share their knowledge to improve the novel fixed wing aircraft. The change agent also needs to change the current mentality at PZL that view M28 as a tier two orphan program. By

demonstrating M28 profitability, the change agent needs to highlight that the aircraft is critical to Sikorsky's future growth. Lastly, the change agent needs to shape the environment factors that ease the automation transition process. Leverage on the success of deflection cover labor hour reduction, M28 should be given formal and equal access to CNC capacities. Senior management should increase investment into design resources needed enable automation transition

By raising M28 program awareness, assigning a dedicated change agent and developing a concrete organizational change plan, PZL will continue to reduce labor cost through the use of automation.

## **Chapter 6. COMMODITY PURCHASING STRATEGY IN PROCUREMENT ORGANIZATION**

Chapter 6 presents the second part of the three-prong approach, which reduces material cost using commodity purchasing strategies at the PZL procurement organization.

### **6.1 PZL procurement organization: current state**

PZL is currently a buying organization instead of a supply chain management one. The procurement organization is divided into two departments: Aircraft Department and General Procurement. The Aircraft Department consists of buyers that purchases components for the various aircraft programs. Their roles mostly consist of placing price quotes and purchase orders. The department also staffs program managers that coordinate procurement activities for individual programs (e.g. BLACK HAWK and M28). The General Procurement department provides several functions. The non-product section purchases manufacturing equipments, office supplies, and executes capital investment projects. The outsourcing section was established recently in order to support the increasing make-to-buy transition activities, aiming to transform PZL from a vertical manufacturing organization to a leaner, more cost-effective one. The section has been a core player of the M28 cost-reduction efforts, contributing to over 50% of the cost-reduction activities. Two additional sections were established to support offloading and sub-contract manufacturing.

Many improvement opportunities existed within the current supply chain organization. First, business requirements (e.g. technology export restriction) and cultural differences place clear divide between buyers from Sikorsky program and PZL programs. The partition is further enhanced by separate SAP systems and production planning processes. Consequently, there are

few interactions between the buyers of the two groups to enable the development of synergistic benefits.

Second, the organization has yet to take advantage of Sikorsky to increase PZL's buyer power. As a whole, Sikorsky and UTCs are major revenue contributors to many of our suppliers. While buyers have begun to use the UTC and Sikorsky name in pricing negotiation, their proposals were dismissed because the products are different from Sikorsky's rotary blade programs and volume concerns. Operating independently, PZL Mielec lacks the name recognition required in pricing negotiation. Furthermore, it has yet to be associated with Sikorsky brand. Most importantly, the first step of increasing buyer power requires negotiation through upper-management channel, and not at the individual buyer level.

Third, there is an urgent need to transform PZL into a supply chain management organization, in order to compete in the cost-driven business environment. For historic reasons described in an earlier chapter, PZL began as an organization that valued self-sustainability over cost-effectiveness. By producing almost everything within the company, there was little need to interact with suppliers, except occasions to source raw materials. For the limited exchanges with external manufacturers, they were coordinated by governmental agencies base on the Soviet socialist model. Since price and volume were pre-determined, there was little need for contract negotiation. As a direct consequence, the procurement group is relatively young and has little international contract negotiation experience. Commodity pricings are often accepted as quoted instead of negotiated aggressively. The group also lacks market research roles to

support the supplier managers. To be more effective, the organization needs to transform from a buying to supplier management organization.

Fourth, the current supplier relationship is coordinated on a case-by-case basis. Each buyer functions independently, and devices negotiation strategy based on her experience. While such practice may function in a more mature company, a budding organization requires greater peer and organizational support. The orders are also placed independently. For example, M28 components are order per aircraft instead of through a fixed multi-year contact. The advantage of economies of scale was not fully utilized at PZL.

Fifth, PZL is facing a great supply chain risk by sourcing majority of its components from the Russian market. Many Russian parts do not follow global standards such as ASI9100. Its casting and rivets have unique sizes and geometries. Consequently, it is difficult, if not impossible to develop second sourcing. One solution is to redesign aircraft components. However the process is limited by qualification requirements and costs. The urgency to re-source is elevated as major Russian manufacturers are entering bankruptcy.

Lastly, PZL lacks a centralized logistics organization. There are currently twenty three warehouses at PZL, most under the authority of the Manufacturing Department. Following lean manufacturing practices, three main warehouses are located adjacent to sub-assembly, sheet metal and machining centers. One additional warehouse supports all the production centers and houses office employees. Currently, the Manufacturing Department focuses mainly on its core competency in production, and provides little management support for warehousing. Consequently, the warehouses are operating independently from each other. In order to

improve lead time and provide more effective inventory control, a centralized logistics management team is required. The Procurement Department currently supports transportation through its bonded customs warehouse. It could potentially develop PZL's warehousing logistics management capability.

A formal supplier management framework is needed to resolve these concerns. It is also an integral part of the M28 cost reduction.

## **6.2 Sikorsky: transition to commodity purchasing**

In 2008, modeling after Pratt and Whitney with the goal of cost reduction, Sikorsky embarked on a journey to transition into commodity purchasing. Sikorsky's procured parts were systematically reclassified into commodity groups. A set of targeted supplier management strategies was developed for each commodity. Four commodities, composites, machined parts, hydraulics and gears were chosen for implementation.

Composite strategies:

- **Expand supply base.** The composite parts were originally consolidated to a few suppliers. In order to develop credible threat needed for pricing negotiations, the supply base was expanded to include additional competitors. Doing so also help to expand supplier capacity required to satisfy future Sikorsky's increasing demand. While there may be increase in qualification cost, the additional product cost savings as well as the development of long-term flexibility benefits outweighs the cost



- **Eliminate proprietary specs.** Using industry instead of proprietary specs enabled Sikorsky to find second source. It was a critical step in the supply base expansion
- **Transition to parametric pricing model.** Prior to strategy implementation, composite pricing was not well understood. It is critical to develop better pricing models based on part characteristic and supplier capability

Machined parts strategies:

- **Develop parts family sourcing strategy.** Under the old practice, parts were requested based on supplier location instead of capability. Parts requested from each supplier were of mixed types, therefore requiring long setup time and heavy capital investment from supplier to develop broad capabilities. The cost was ultimately transferred to the customers. Under the new strategy, parts were grouped and distributed to suppliers based on similar processing requirements. Doing so reduced production cost. It also lowered qualification cost. Groups of parts are qualified instead of individual parts. Re-qualifications of the same parts from different suppliers were eliminated. Lastly, suppliers were competing on bundles of parts, forcing them to take on profitable parts as well as non-profitable ones
- **Re-source from lower cost location.** Under old strategy, parts were sourced mainly from northeastern regions close to the Sikorsky headquarter in Connecticut. Analysis showed that relocating source to Midwest, factoring in added transportation cost, still provide substantial cost savings. The new strategy included developing current suppliers capability in other regions, as well as bringing in new suppliers

- **Increase parts purchased under long term agreement (LTA).** Under the old practice, majority of machined parts were bought under non-LTA. The lack of economies of scale was reflected in higher pricing. LTA reduced supplier risks and manufacturing cost

Hydraulics strategies:

- **Expand supply base.** Similar to composites, the hydraulics supplier markets were dominated by few players. Under the new strategy, Sikorsky will expand supplier base and establish dual sources. Increasing competition forced incumbents to reduced price and improved quality
- **Engaged in Joint Process Improvement.** Improve parts quality through joint process improvement with suppliers

Gears strategies:

- **Supplier consolidation.** Gears were commodity products that depended on volume. In order to leverage on economies of scale in pricing negotiation, the supplier based were consolidated
- **Re-source from lower cost location.** Under the new strategy, the parts were resourced from Midwest as well as Eastern Europe, in order to take advantage of lower labor cost

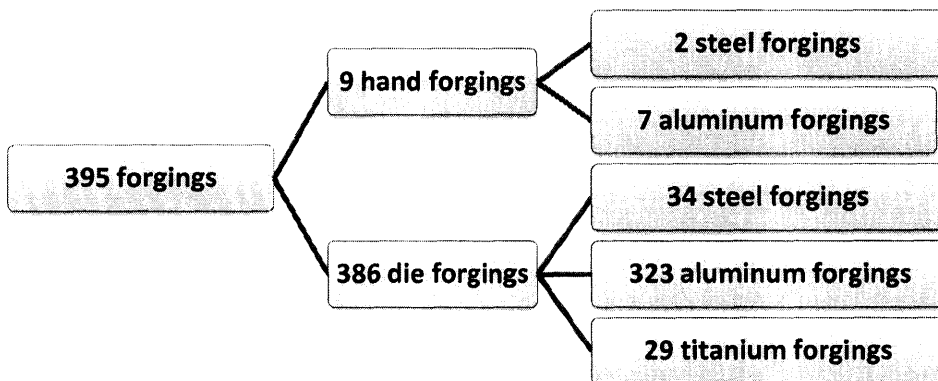
### 6.3 PZL procurement organization: future state

This thesis develops a set of commodity purchasing strategies for PZL procurement organization, modeled after those of Sikorsky. M28 Optimization Team is expected to use these strategies to reduce material cost.

The current M28 commodities are first divided into six categories. There are two non-product groups: the tooling and equipment, and capital expenditure (CAPEX) projects. There are four product groups: avionics and electronics, raw material, machined parts, and composite and aircraft interior furnishing. The raw material, which composes of forging, casting and fasteners, as well as avionics and electronics will be presented as case studies here.

### 6.3.1 Forging and casting strategy

Forging and casting structures are currently outsourced and purchased from six suppliers. Since Sikorsky purchases for its BLACK HAWK program separately, all the current forging and casting purchasing are to support the M28 program. There are 395 forging parts, manufactured by hand forging and die forging (Figure 35). The breakdown is illustrated below:



**Figure 35: PZL forging components**

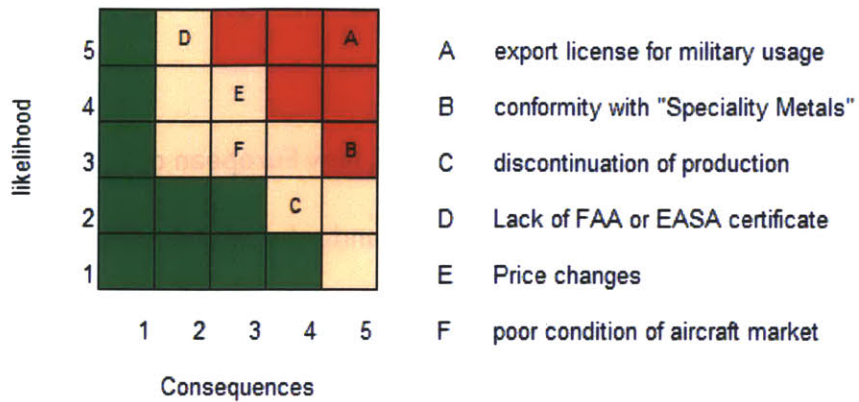
Forging components are analyzed based on the three material groups: steel, aluminum and titanium. The titanium group consists of three types of materials with three suppliers. This group has the highest risk since it is mainly sourced from Russia. The risks are:

- **Financial risk.** Due to economic decline, poor condition of aircraft market and reduction in demand, many Russian manufacturers and suppliers are facing bankruptcy. One critical M28 forging was purchased from a Russian supplier ten years ago. Since the last purchase, the distributor went bankrupt, taking along with it the manufacturer and tooling information needed for future orders. Regrettably, the unknown manufacturer was the sole-source for the forging. To replenish diminishing stocks, PZL needs to manufacture the forging by itself, or help other manufacturers to develop the capability. In both scenarios, PZL will need to incur large capital investment
- **Market risk.** US military prohibits the use of Russian materials for its aircrafts. Specifically, US Department of Defense prohibits the purchasing of “Specialty Metals” (titanium, beryllium and a number of other different metal alloys) and products containing special metals unless they are melted or processed in the US. Consequently, a replacement is required to enable M28’s penetration into the US military market. Furthermore, the Russian material lacks FAA or EASA certificate. In order to develop second-source, PZL will need to help new manufacturers to carry the hefty certification cost
- **Availability risk.** TI-88 titanium material was recently patented by a Russian research institute. Enjoying monopolistic control of the technology, the institute raised royalty fees and demanded large premium on TI-88 forging exports. Unfortunately, Russian manufacturers could not bear the high export cost. Consequently, there was a virtual export embargo of TI-88 from Russia for over a year. The institute’s block on production

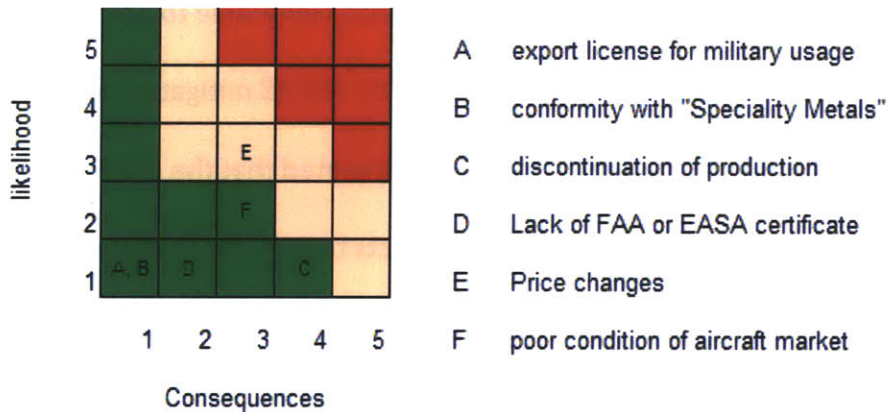
was lifted recently. Nevertheless, the potentials for future embargos on TI-88 and other titanium materials remain high

To reduce risk on titanium forging supply chain, new European or U.S. materials will need to be developed. A compatible American AMS standard material AM-88 is analyzed as a potential replacement. Comparative risk assessments are completed for TI-88 and AM-88 (Figure 36 and Figure 37).

With TI-88 forging, the export and regulation risks are highly likely with maximal impact as they limit product entrance into the US market. It is also vulnerable to price hikes since the technology is patented and tightly controlled. US certified AM-88 mitigates such concerns. In additions to independence from Russian market, it is estimated that the material and labor cost will reduced by 25%. However, there are negative aspects to material changes as well. First, PZL will need to develop its own forging capability. Currently, there is no manufacturer who is capable of producing PZL forging using AM-88. Outsourcing will require significant time for suppliers to develop forging capability. It will be a 150k+ USD capital expenditure, with PZL bearing full financial risk. Forging components will need to be redesign and tested. If the test of new material will not meet certification requirements, the entire aircraft may need to be re-certified.



**Figure 36: TI-88 forging risk assessment**



**Figure 37: AM-88 Forging Risk Assessment**

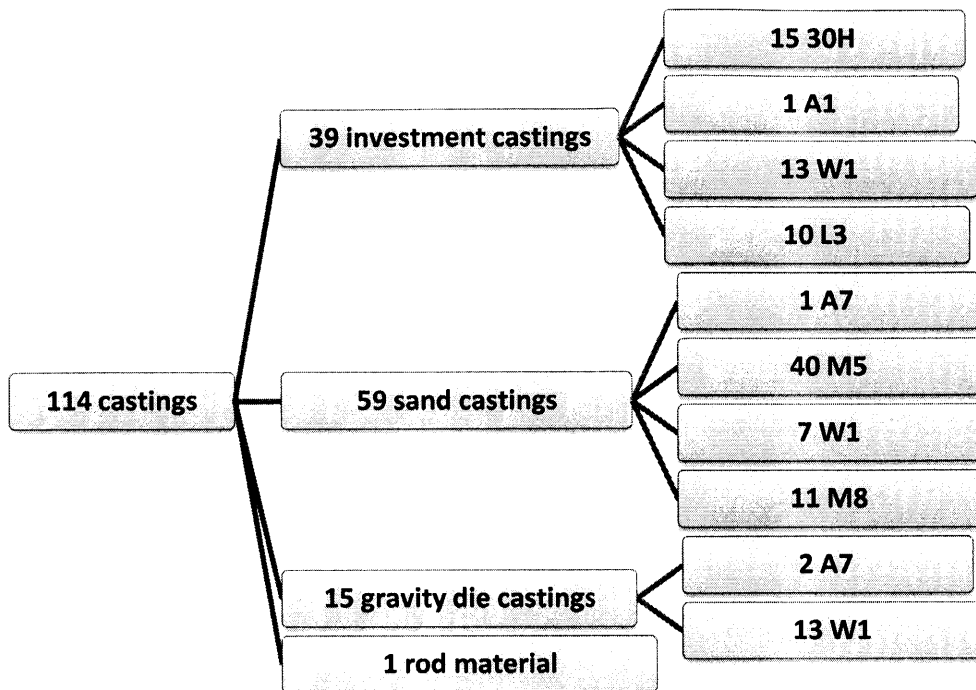
Aluminum forging is currently sourced from single Polish supplier. This material makes up over 75% of total forging spending, since aluminum is the main material used for M28 aero-structure. In contrast, other Sikorsky programs relies less on aluminum, therefore buy less in volume. PZL could potentially leverage on its volume to negotiate better pricing for other Sikorsky programs. Risk analysis shows that aluminum forging's major risk is the financial position of its supplier. Consequently, second supplier may be developed to alleviate risk.

The forging suppliers are also analyzed based on consolidation potentials. The goal is the reduced the total number of suppliers down to three, with each supplier owning one material. Since the suppliers lack manufacturing capability for multiple materials, further reduction in supplier is not possible.

Titanium forging will be sourced directly from a single manufacturer instead of from the current distributors. L is a US forging company currently supplying steel components for Sikorsky. The company acquired a Polish company Z in 2005, with the goal of establishing in-house titanium manufacturing capability. Since the acquisition, PZL and Sikorsky have jointly provided the demand required to enable the development of the new factory. Consequently, the supplier transition will bring major synergistic benefits internal to Sikorsky's organization.

Long term agreement is also expected to replace the current individual Purchase Order (P.O.) based buying practices. Specifically, LTA usage will increase from current 1% to 100%. Doing so allows PZL to enjoy lower pricing as a result of reduced supplier risk and increased purchasing base. Inventory management will expect to improve with schedule agreement. With high volume, product and service qualities as measured by On-Time-Delivery (OTD) and Parts-Per-Million (PPM) metrics will be improved. Consequently, with better services, LTA helps to foster long term relationship with suppliers. In fact, with a well-developed relationship, distributors may be eliminated. Lastly, LTA will also be jointly-created with other Sikorsky division to maximize synergistic benefits.

Similar analysis was completed for casting (Figure 38). There are 114 castings, sourced from 4 suppliers.



**Figure 38: PZL casting components**

The casting supply chain faced similar financial risk as the forging supply chain. Specifically, C1 material is currently being investigated as a replacement to W1 materials. A major investment casting supplier also went bankrupt. Like titanium forging, PZL is currently helping local manufacturer to develop casting ability. The supply base will also be consolidated so that PZL will only interact with two manufacturers.

### 6.3.2 Fasteners strategy

Fasteners are another major commodity used in the product of M28. Each M28 uses over 400,000 fasteners worth \$300K USD. There are 4500 unique part numbers and 180 types, ranging from washers, bolts to screws. In addition to in-sourcing, 17 suppliers are currently used to purchase fasteners products. The main goal of fasteners strategy is to reduce complexity of a very generic commodity. Product segmentations were first performed.



The commodity is first segmented by part number and types, to analyze the number of unique part numbers purchased for each type (Figure 39). The five types with the most unique part numbers are: rivets (800 P/Ns), screws and pads (500 P/Ns), threaded screws (450 P/Ns) and nuts (300 P/Ns). Due to non-standardization, especially with Russian materials, there are over diversification of part numbers for different fasteners type. The opposite is true as well. There are 146 fasteners types with less than ten part numbers each. As a result, there is room to consolidate fasteners type.

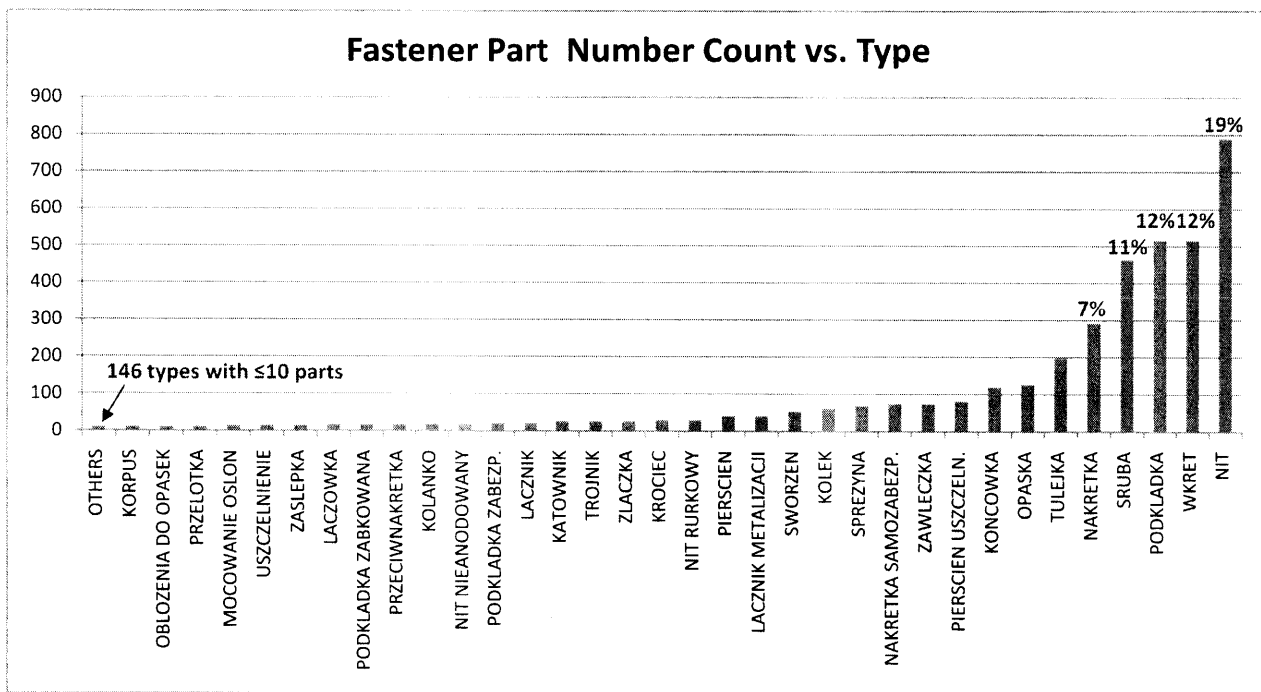


Figure 39: Fastener part number count vs. type

Analysis also shows that most of the part numbers are rarely used (Figure 40). There are less than 76 part numbers with high usage of greater than 1000 counts per aircraft. Only 15 part numbers have values of greater than 10K PLN (or \$3K USD) per aircraft (Figure 41). On the other hand, over 2800 part numbers, or over 75% of total part number counts, have usage of

less than 50 parts per aircraft. 75% of the part numbers have less than value of 500 PLN (or \$166 USD) per aircraft.

Not all complexities of the fasteners portfolio can be reduced. There are low volume parts that are unique to the aircraft design and cannot be replaced easily, mainly due to high requalification cost, or the specifications of the aircraft components being installed. For other fasteners, the strategy is to consolidation to achieve high volume high value for minimal fastener P/Ns and types.

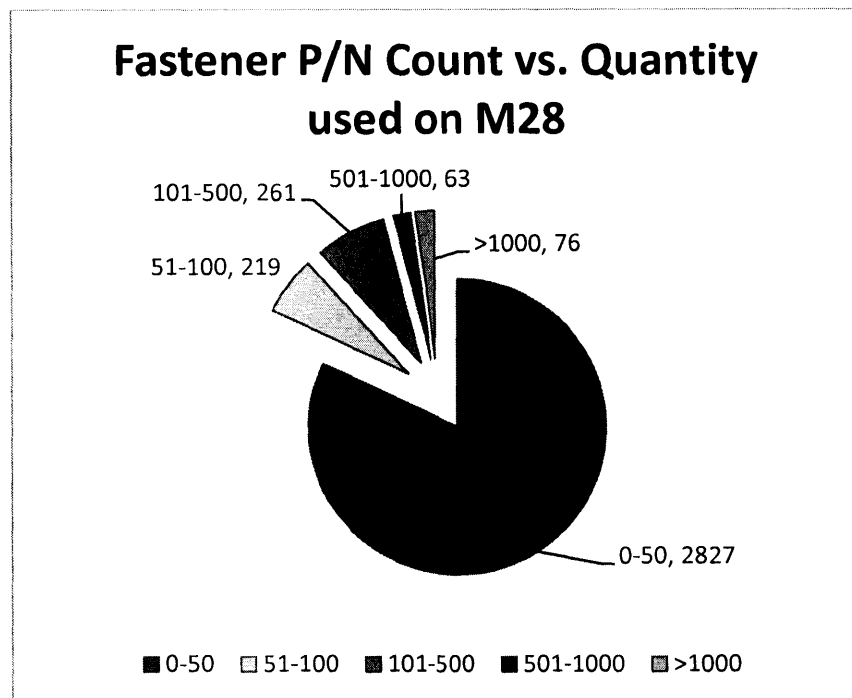
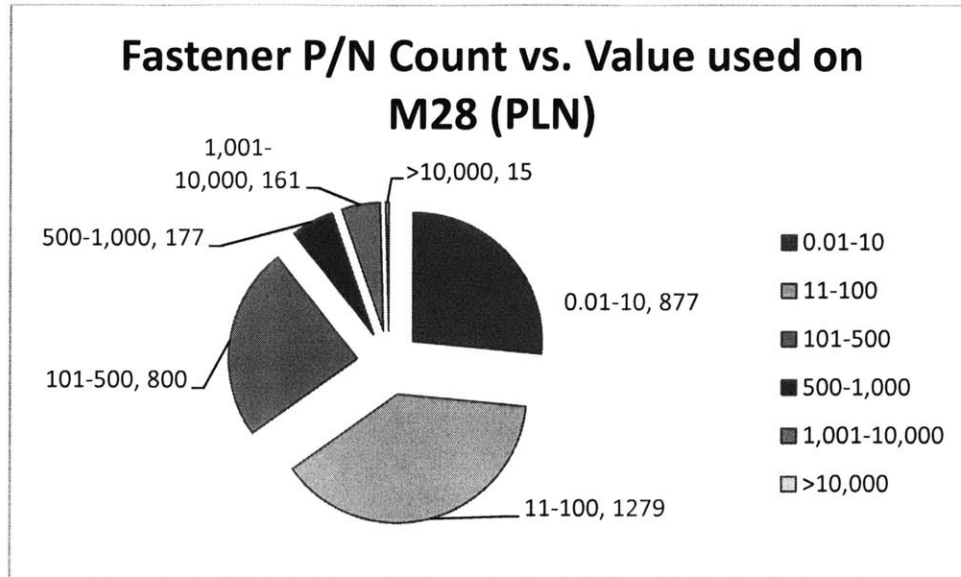


Figure 40: Fastener part number count vs. quantity used on M28



**Figure 41: Fastener part number count vs. value used on M28 (PLN)**

Fasteners commodity was also segmented by suppliers (Figure 42). Currently 12% of fasteners are manufactured at PZL. In the early 2000's, more than 94% percent of fasteners were produced at PZL. As part of the former socialist structure, PZL was functioning as a self-sustaining factory. It manufactured everything down to the sub-component level. The first wave of outsourcing has dramatically reduced in-source fasteners to the current percentage. The end-goal is to have PZL focusing on its core competency of manufacturing aircraft, and completely outsource fasteners production. However, many of the remaining fasteners are highly specialized. To outsource, PZL need to invest in external manufacturers to first build up their manufacturing capabilities. However, given the low volume requirement set by M28, PZL lacks the economies of scale needed to convince external factories to take on additional burden. PZL's key potential leverage is to use bundling to combine high volume rivets with specialized low volume fasteners. There are also after-sales parts that PZL can use as leverage.

Unfortunately, the per-aircraft value is only \$57K USD, unsubstantial compare to the overall fasteners value of \$300K USD.

Among the 88% fastener currently outsourced, 59% is supplied by a local Polish manufacturer EM, and 22% is supplied by WTL. Unfortunately, quality and shortage problems have plagued fasteners sourced from EM. Consequently, PZL would like to resource the fasteners from EM as well.

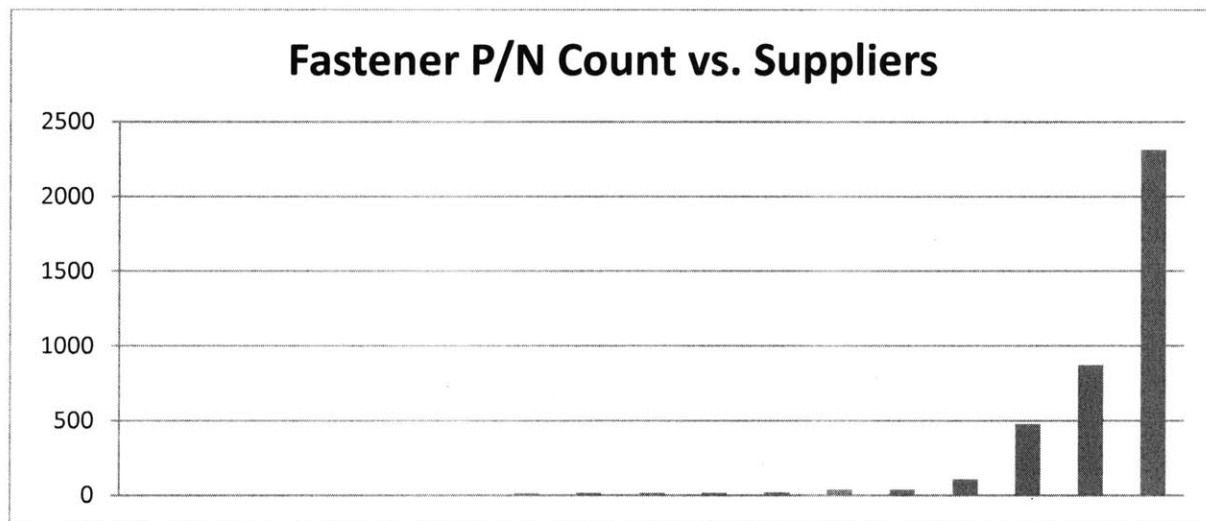
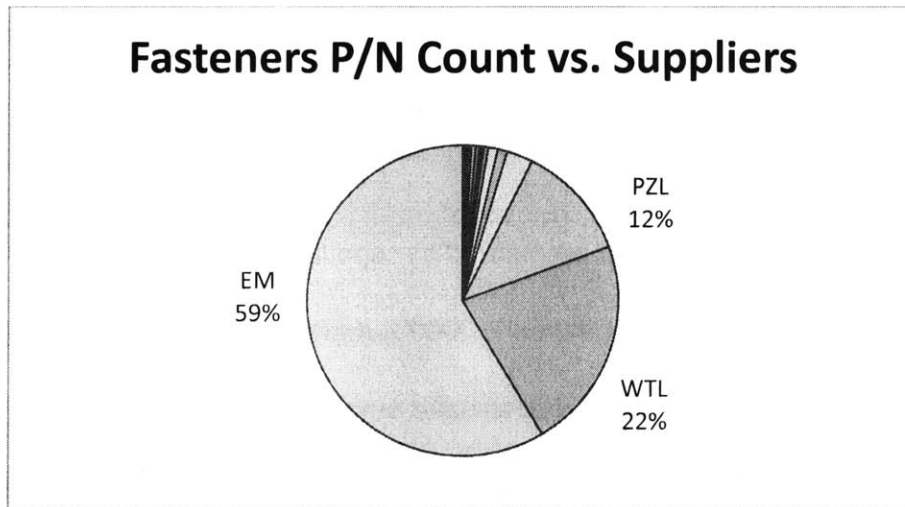


Figure 42: Fastener part number count vs. suppliers

To manage commodity more effectively with minimum management cost, PZL's fastener strategy is to outsource fasteners management to a single external supplier. There are multiple objectives that PZL would like to achieve:

- **Single-point sourcing.** A single supplier will be selected to manage relationship among the remaining consolidated suppliers
- **Consolidations.** PZL design will work aggressively in reducing the number of unique part numbers as well as fastener types. With reduced parts used, PZL will work with the single supplier to reduce the number of sources for fasteners
- **Modernize sourcing operations.** The single supplier will provide just-in-time delivery and sorting service. It will implement Kanban cabinets at PZL production department, with a dedicated staff that refill cabin on a daily basis. A sufficient fasteners stock will be kept to eliminate shortage problems and ensure on-time delivery. To minimize overstock, the single-point supplier owns fastener inventory until it is used by the production department
- **Outsource.** PZL will also work with the single suppliers to outsource the remaining fasteners currently manufactured at PZL
- **Special processing and quality requirements.** In order to minimize quality problems that were faced with EM, Sikorsky supplier gold program will be implemented to ensure quality. Additional processing of fasteners will be provided by the single-point supplier as well

There are two single-point supplier candidates currently being considered. As shown by the list provided above, PZL requires extensive high-quality service from the supplier.

Detailed financial analysis has determined a service fee that yields outsourcing supplier management as a more favorable option. Supplier A does not have working relationship with PZL. Consequently, PZL could negotiate a better price, since it could offer supplier A additional business with other M28 commodities and other high-value program including the famed BLACK HAWK. On the other hand, supplier B already has an established relationship with PZL on the BLACK HAWK program. Consequently, it is less willing to take on the low-margin high-complexity M28 fastener business. However, they have demonstrated outstanding results on the BLACK HAWK program, with lean inventory management system and on-time delivery. With existing supply chain at PZL, the marginal cost of extending service to M28 is relatively low.

### **6.3.3 Avionics and electronics strategy**

Avionics and electronics on M28 aircrafts range from navigation systems, radio compass, Electronics Flight Instrument System (EFIS), Emergency Locator Transmitter to power systems. They are purchased separately for the civilian, 05, and military version of M28, Bryza, and on a per-aircraft basis. All components data has been collected and analyzed based on pricing, supplier and manufacturer. The commodity consists of 399 unique part numbers. For illustrative purposes, only M05 analysis is presented here. Similar sets of recommendations have been presented to Bryza as well. There are several issues with the current procurement practices:

- **Purchase through distributor instead of direct buy.** These components are manufactured by 53 manufacturers. At the same time, PZL sources from 47 suppliers,

many of them are not the OEMs. An illustrative example would be the approximately 50% of the avionics manufactured by AA, a major conglomerate company that manufactures aerospace systems. Given AA's dominant presence in the market, such figure is comparable among the aircraft manufacturers. However, PZL was required to purchase component through BEE, a Czech Republic based distributor for AA. Such policy was mainly due to PZL's low order volume. Consequently, PZL lack the customer power needed to interact directly with AA. As a result, the presence of a third-party distributor adds on additional transfer cost and increases M28 avionics cost

- **Geographical/Political Risk.** An immediate consequence of sourcing through distributors is the discrepancies between supplier and manufacturer locations. Currently, over 70% of avionics are purchased from Poland and Czech Republic, Eastern European countries (Figure 43). One Polish supplier is critical in consolidating the sourcing of Russian-made avionics. As was the case with forgings, Russian avionics are high risk components. There is volatility in pricing, the risk of parts shortage, as well as the difficulties in establishing second source. Since BEE is the major source of AA avionics, Czech Republic is a major sourcing location.

On the other hand, majority of the parts are manufactured in Western Europe as well as in the US (Figure 44). While AA components are distributed through Europe, the manufacturing operations are located in the States. On the other hand, companies such as Northrop Grumman, Goodrich are located in Germany and UK, and are major manufacturers of Attitude Heading Reference System (AHRS) and power systems. Discounting BEE, Czech Republic accounts for only 1% of manufacturing.

The discrepancies highlight three important concerns. First, since majority of manufacturing is located oversea, sourcing from locations near Mielec Poland does not help to reduce transportation cost of the product. Second, many avionics are low demand products that are order on demand by the suppliers. Consequently, economy of scale, the key advantage of using third-party distributor, is almost non-existent. Third, the significant portion of avionics produced by Russian manufacturers continues to present supply chain risk

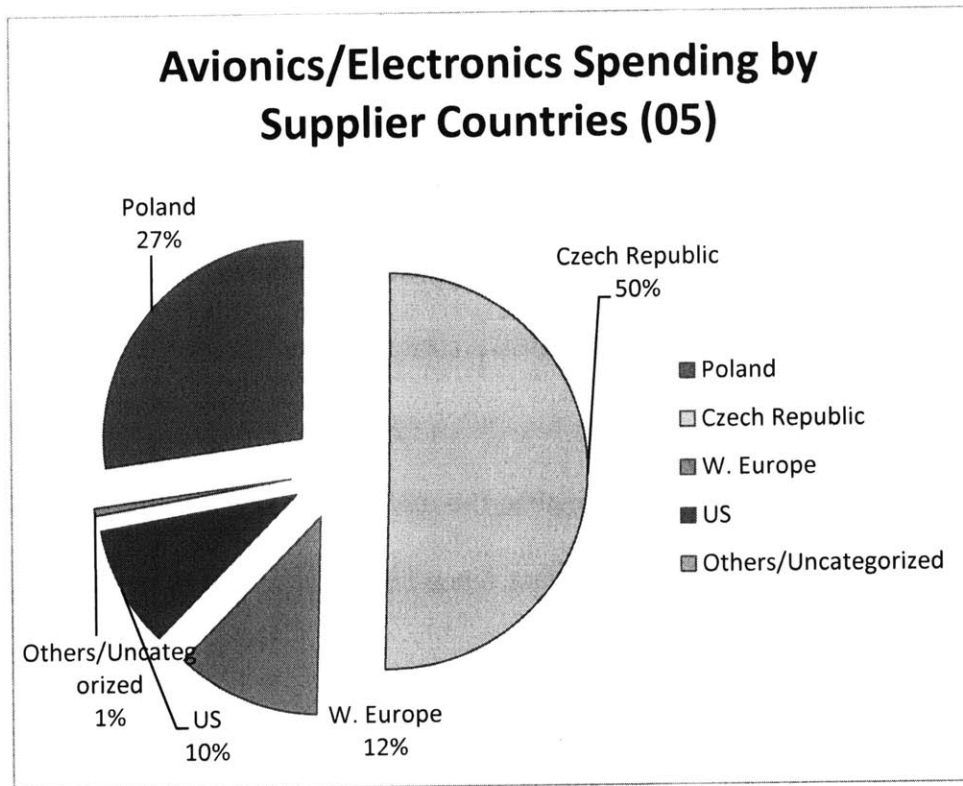
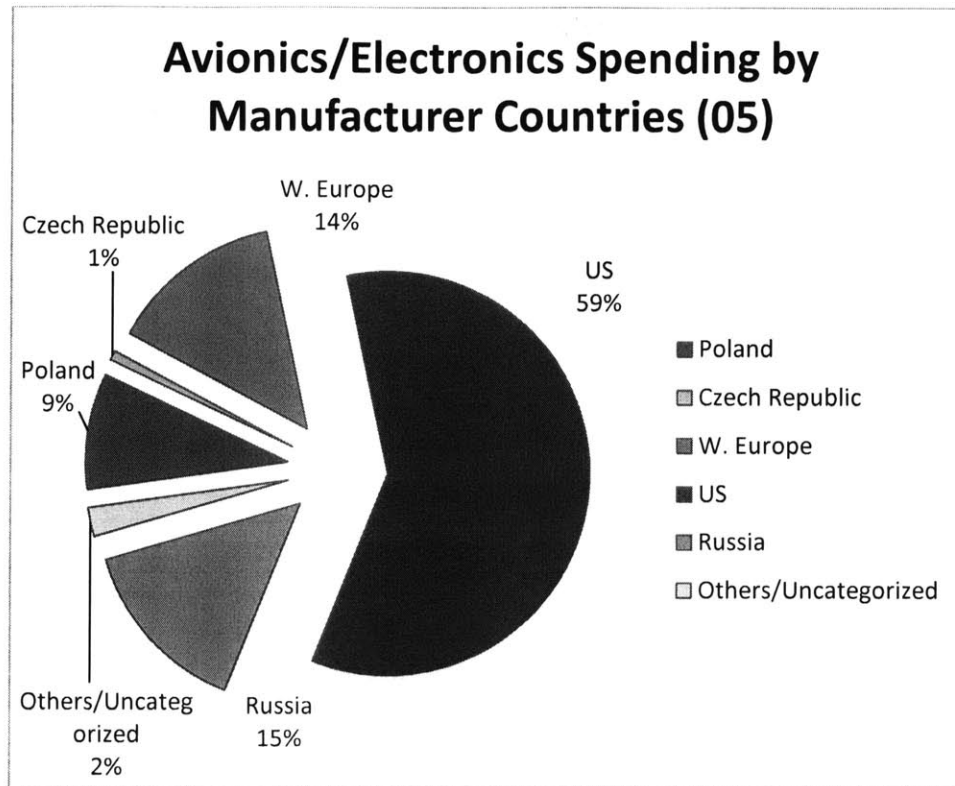


Figure 43: Avionics/electronics breakdown by supplier countries

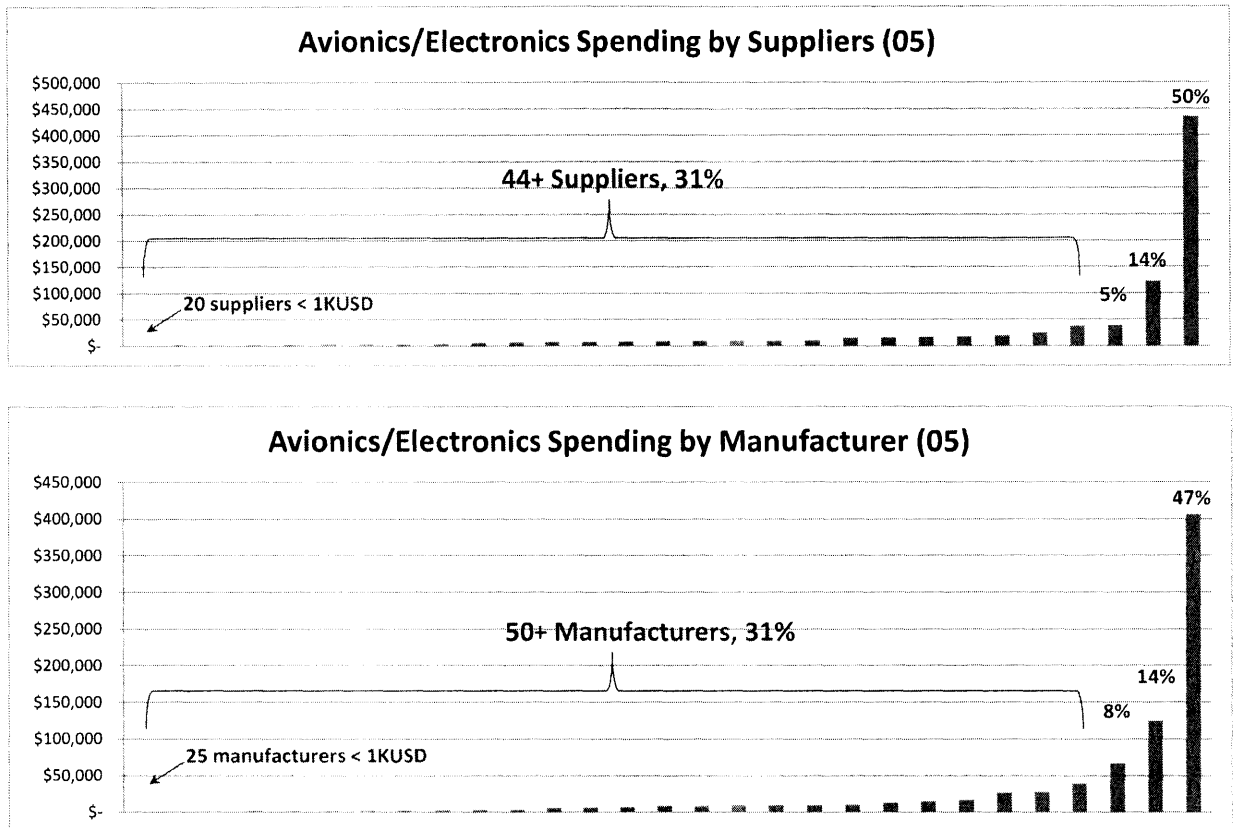




**Figure 44: Avionics/electronics breakdown by manufacturer countries**

- Existence of Long Tail End.** Approximately 70% of avionics and electronics are produced and sourced from the top three manufacturers and suppliers. Furthermore, 20 suppliers and 25 manufacturers are supplying components worth less than \$1K USD per aircraft (Figure 45). On the manufacturing side, selected parts are integrated to the aircraft design, resulting in significant qualification cost in using replacement parts. However, the trade-off between qualification cost and avionics cost reduction must be studied in more detail. Given the large percentage of components with cost reduction potentials, the benefit may outweigh the additional qualification cost. On the supplier side, consolidating purchasing through fewer suppliers will reduce supply chain logistics cost. Supplier could rely on economies of scale to reduce inventory storage and

transportation cost. PZL could reduce supplier management cost, and allocate buyers on additional procurement improvement opportunities



**Figure 45: Avionics/electronics spending by suppliers and manufacturers**

A set of supplier management strategies is created to resolve these concerns. First, there needs to be transition from a distribution to a direct-buy model. Doing so reduce the cost associated with using third-party distributors. As a subsidiary of Sikorsky and UTC, PZL can leverage on the buying power of its parent divisions to directly negotiate pricing with AA. At the same time, PZL could formulate bundling long-term agreements with its sister divisions to further bolster its negotiation leverage. Just as forging, a long-term five year agreement instead

of per-aircraft purchase order should be implemented with suppliers to take advantage of economies of scale.

Implementing direct-buy will also transform the sourcing location from Eastern Europe to Western Europe and the US. Nevertheless, significant portion of avionics is still manufactured at Russia. Consequently, a better understanding qualification cost will need to be studied, in order to understand the tradeoff between aircraft re-qualification cost and cost savings from low-risk avionics.

#### **6.4 Summary and recommendations**

Sets of commodity purchasing strategies have been developed for raw materials (fasteners, forging and casting) and avionics and electronics.

To summarize, forging and casting supplier strategies are:

- Explore new material to become independent from Russian market
- Interact directly with manufacturers, bypassing distributors
- Consolidate suppliers
- Formulate LTA
- Formulate bundling LTA with other Sikorsky subsidiaries

The supplier management strategies for fasteners are:

- Develop single-point sourcing
- Consolidate suppliers

- Reduce supply chain complexity by consolidating and minimizing the number of fasteners type
- Modernize sourcing operations
- Outsource remaining fasteners manufactured at PZL
- Ensure quality and special processing requirements.

The supplier management strategies for avionics are:

- Transition from distributor to direct-buys
- Consolidate suppliers of low volume parts to less than five suppliers
- Manufacturers: Cost-benefit analysis of saving using non-Soviet avionics and re-certification cost
- For large manufacturer (e.g. AA) form bundling LTA with Sikorsky
- Transition from P.O. to LTA

Similar strategies should be developed for machined parts and composite and aircraft interior furnishing commodity groups. The development processes, like those of the strategies outlined in this chapter, must incorporate the current buyers in the procurement organization. This is critical in ensuring that the strategies address the unique needs of every buyer. Furthermore, it helps to empower buyers as change agents in the transformation of the procurement organization into a supply chain management one.

The current culture in the procurement department will also need to be changed. Due to export restrictions, the BLACK HAWK procurement activities will remain separated from those of M28. However, job rotations between the two programs could increase knowledge

sharing. At the end of this internship, member of Sikorsky's Operations Leadership Program has been assigned to the M28 program. Such employee is critical in promoting knowledge sharing, as well as raising awareness of the M28 product.

PZL also needs to either develop a centralized logistics organization, or outsource to external purchase-to-pay (P2P) service providers. Given PZL's core competency lies in aircraft manufacturing, compounded by lack of labor resource, it should outsource transportation and logistics activities.

## Chapter 7. KAIZEN EVENTS ENABLING REDESIGN FOR MANUFACTURING

### 7.1 Kaizen event framework

While automation and commodity purchasing strategies help to reduce product cost, radical redesign for manufacturing is needed to reach the ambitious 28% target. In fact, a large percentage of automation projects require product redesign. A Kaizen event based on Octopus Fishing concept will be described here. Unlike the continuous process described in previous chapters, these are discrete annual or biannual two-week Kaizen events. Each event invites all functional representations from different UTC subsidiaries. Despite the differences in product offerings, the process expertise of each subsidiary could be applicable across product portfolios. Furthermore, procurement improvement activities often include the development of bundling among subsidiaries to increase negotiation power with suppliers. Based on these two factors, Kaizen events are invaluable opportunities for consolidating resources and knowledge.

Each event consists of multi-step processes which are:

- **Team formation.** Before the beginning of the event, three teams, Finance, Manufacturing and Purchasing will be formed. Every team consists of representatives from manufacturing, design, sales/marketing, procurement and finance departments. It is critical to include representatives from other Sikorsky and UTC subsidiaries
- **Break down M28 into independent subsystems.** The entire M28 structure will be broken down to less than fifteen subsystems with minimal interdependency, to ensure cost reduction recommendation on one subsystem will have a limited effect on other subsystems

- **Finance team assigns cost to subsystem.** Engineering helps finance to translate numbers from SAP to physical components
- **Divide subsystems into “make” vs. “buy”.** Assign “make” subsystems to the Manufacturing team and “buy” subsystems to the Purchasing team. For example, the power-plant, avionics and electronics, undercarriage and interior subsystems will be assigned to Purchasing team. Fuselage, wings and empennages will be assigned to Manufacturing team
- **Evaluation.** For every subsystem, evaluate all potential alternatives to the current solution. Do not be satisfied with one alternative, with a minimum requirement of at least 5 alternatives to be generated. The team should ask Five Whys to understand the differences between current solution and cheapest alternatives. The team should consider additional “make” vs. “buy” options. The best alternative will then be selected based on costs and risks. A set of recommendations will then be generated with cost reduction clearly specified
- **Project prioritization.** Re-order subsystems based on the cost reductions calculated in recommendations. Prioritize and select projects with highest cost reduction potentials
- **Conclusion and next step.** After the end of the event, event leader need to calculate the total cost reduction potentials of projects selected. If cost reduction is greater than 28%, the leader needs to evaluate margins and risks, formulate contingency plans, and perform active cost tracking during implementation. If cost reduction is less than 28%, the leader should consider re-running the Kaizen events with larger teams. More

projects from the current event could also be included, but at the risk of executing low value projects

## **7.2 Summary and recommendations**

A two-week Kaizen event has been developed based on UTC Otis' Octopus Fishing method. It will play a critical role in promoting aircraft redesign.

Several key areas need to be paid special attention to, in order to increase effectiveness of Kaizen events. First, they are only effective with a large international cross-functional participation. Having an explosive amount of ideas generated is critical to event success. Benchmarking against similar products will also help to improve event effectiveness. Cost figures must be accurate. Unlike benchmarking against outside competitors, data should be readily available for benchmarking against other internal divisions. However, ensuring accurate data requires tremendous resources, which limits the frequency of Kaizen events. To ensure continuing active participation from all subsidiaries, each event should not be viewed as another Kaizen event with minimal impact. The financial benefit of each event should be clearly and thoroughly described by leadership. The event leader should also evaluate carefully which external suppliers and customers to include at the event, balancing idea generation with intellectual property concerns. Lastly, the event requires obtaining "buy-in" from design engineers for redesign. Engineering should relentlessly question engineering requirements, trying to understand if they transfer into real end-user need with tangible value. By following these concerns closely, effective Kaizen events can be implemented.



## **Chapter 8. CONCLUSION**

In today's environment of globalization, a market-based product development process focusing on aggressive cost requirements are critical for a company's success. This paper links top-down M28 cost structure and bottom-up cost reduction effort, to develop a systematic finance-driven cost reduction process. To enhance the number of effective ideas generated, a three-prong approach that focuses on automation in the manufacturing organization, commodity purchasing strategy in procurement organization and Kaizen events for promoting redesign for manufacturing has been presented. With corresponding cultural and process improvement, PZL could work effectively toward the cost reduction goal.

Numerous follow-up projects exist for the M28 program. Execution-based projects in selected areas presented by this thesis will be beneficial to ensure successful implementation. Procurement related projects include the integration of Sikorsky and PZL procurement organizations in forming bundling LTAs, building local manufacturers capabilities to enable outsourcing, and executing commodity strategy in a given commodity group. Manufacturing related projects include capacity planning for resource distribution between ramping production of M28 and BLACK HAWK. Planning, gathering resources and executing effective Kaizen events will also be a highly valuable project.

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## **Appendix**

### **A. M28 competitors descriptions**

#### **A.1 Viking Air DHC-6 Twin Otter 400**

The DHC-6 Twin Otter is a Canadian 20-passenger STOL utility aircraft developed by de Havilland Canada in 1965. After the last DHC aircraft series, Series 320, ceased production in 1988, the toolings were purchased by Viking Air.(de Havilland Canada DHC-6 Twin Otter) The redesigned aircraft, Series 400, and expected to make first delivery by the second quarter of 2010. Assembly work will be shared between facilities in Calgary and Vancouver. Like M28, Twin Otter has a fixed tricycle undercarriage, with STOL abilities and high rate of climb. It also utilizes twin PT6A turboprop engines that allow an increase in payload while retaining the renowned STOL quality. The latest Series 400 Twin Otter includes Honeywell Primus Apex fully integrated avionics, deletions of the AC electrical system and beta backup system, modernization of the electrical and lighting systems, and use of composite for non-load-bearing structures such as doors. Twin Otters could be delivered directly from factory with tricycle landing gear fitting as well as ski and floating, options unavailable in M28.

Given its long operational history and large fleet size, Twin Otter has achieved high degrees of brand recognition and loyalty. It has been very successful as a cargo, regional passenger airliner and MEDEVAC aircraft. It has also been popular with commercial skydiving operations, capable of carrying up to 22 skydivers to over 13,400 ft. US Air Force uses Twin Otters for its US Army Parachute Team. With it ski fitting, Twin Otters are a staple of Antarctic

transportation.(NSF) On April 24-25th, 2001, two Twin Otters performed the only winter flight to Amundsen-Scott South Pole Station to perform a medical evacuation.

Twin Otter is also widely used by 120+ regional commercial airlines, with a total 600+ in service worldwide. Malaysia Airlines uses the Twin Otter exclusively for passenger and freight transportation to the Kelabit Highlands region in Sarawak. In the United Kingdom, the FlyBe franchise operator Loganair uses the aircraft to service the island of Barra in the Hebrides Island. The Twin Otter is also used for landing in the world's shortest commercial runway on the Caribbean island of Saba, Netherlands Antilles. Such long and impressive operational history has provides Twin Otter the competitive advantage that other smaller players, such as M28, lacks. With high product demand, Viking Air will continue to enjoy cost advantage through economies of scale.

## **A.2 RUAG Aerospace 228 New Generation**

228 is a twin-turboprop STOL utility aircraft, manufactured by Dornier GmbH from 1981 until 1998.(Dornier Do 228) In 1983 India's Hindustan Aeronautics (HAL) bought a production license and manufactured the 228 for Asian market. Approximately 270 Do 228s were built, and currently more than 127 aircrafts remain in airline service. Near the end of 2007, Switzerland's RUAG Aerospace announced a new upgraded model to satisfy the 15-19 seat utility aircraft market. RUAG has commenced building a Dornier 228 New Generation in Germany using structural parts supplied by HAL. It retains the original aircraft design but with improved technologies and performances, such as a new five blade propeller made with composite materials, glass cockpit and longer range.(RUAG) NG is expected to make first delivery in 2010.

Keeping costs contained was important to the new program. As a result, RUAG decided to make no changes to the aircraft that would affect its type certificate.(Forecast International) Improvements to the aircraft such as the addition of Rockwell Collins avionics, a glass cockpit, a hydraulic system from Liebherr, and new five-bladed MT props have all already been certified under previously awarded supplementary type certificates. The company has said publicly that it will need to invest no more than EUR10 million in the program because it retained the aircraft's jigs, drawings, and type certificate, so the risk in moving ahead with production remained low. An official at RUAG promised a 15 percent lower fuel burn from the aircraft's Honeywell TPE331-10 engines.

HAL continues to be a main supplier, building the aircraft's fuselage, empennage and other structural parts in India. However, final assembly of the aircraft will be completed at the former Dornier plant in Oberpfaffenhofen, Germany (outside Munich).

Unlike other M28 competitors, Dornier uses Garrett AiResearch TPE-331 turboprop engines instead of Pratt and Whitney Canada PT6A. It also utilizes a unique wing structure, the TNT, developed by Dornier GmbH in the late 1970e. Two different fuselage variants (15 and 19 passengers) were developed for Do 228-100 and Do 228-200. It has retractable landing gears.

### **A.3 CASA C-212-400**

The EADS CASA C-212 Aviocar is turboprop STOL medium transport aircraft designed and built in Spain for civil and military use.(CASA C-212 Aviocar) During the late 1960, CASA developed this aircraft as a modern alternative to the outdated Junkers Ju 52 and Douglas C-47 used by the Spanish Air Force. It immediately achieved success with the military and the

commercial sector. The Aviocar name was discontinued after the FAA certification in 1977. While C-212 was mainly built in Spain, Dirgantara Indonesia (Indonesian Aerospace, IAe) in Indonesia secured the rights for license production since 1976.

A prototype of the new C-212-400, converted from a CASA stock aircraft, made its initial flight in April 1997. (Forecast International) In April 2009, EADS formally merged EADS CASA Military Transport Aircraft Division (MTAD) with Airbus Military into a new business unit named Airbus Military. The production of C-212 was transferred to the new unit as well. All C-212-400 built to date have been produced only at Airbus Military facilities in Spain, and not certified for civilian use in the United States. However, an agreement was signed in November 2006 between EADS CASA and IAe, to transfer entire C-212-400 production and assembly from Spain to Bandung, Indonesia. The production toolings were sold for \$15m, (Jane's Information Group) and transfer process was expected to complete "over next fourteen months". The first aircraft was expected to be delivered in 2011. Under the agreement, IAe will market a transport version to Indonesian and ASEAN zone customers. CASA is to assist in marketing and mission system integration of maritime patrol version.

Meanwhile, IAe continues to build the C-212-200 version. Brazilian Air Force also expressed interest in C-212-400 to fill its CT-X requirement for a new light tactical transport. 50 aircrafts are to be assembled locally in Brazil on an assembly line established at the Air Force's Parque de Material Aeronautico maintenance center in Campo de Marte, Sao Paulo. However, it is unclear whether the collaboration will proceed.



Similar to Dornier, the plane uses Garrett AiResearch TPE-331 engines. It has a high-mounted wing as M28, a conventional tail, and a fuselage that could seat 21-28 passengers. Its fuselage is also non-pressurized, limiting the aircraft to low-flight-level airline usage. It has a non-retractable tricycle undercarriage. There is a passenger door located at the rear of the aircraft. Its latest Series 400 uses updated avionics and other aircraft systems.