PRELIMINARY

LEAN AIRCRAFT INITIATIVE
SUPPLIER SYSTEMS AND RELATIONSHIPS

LEAN PRACTICES AND METRICS
TOWARD A DEFINITION OF A LEAN ENTERPRISE MODEL FOR THE DEFENSE AIRCRAFT INDUSTRY

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NOTE: Draft; for review and comments only. The preliminary results reported in this document are based on two meetings of the Supplier Systems and Relationships Lean Enterprise Model (LEM) Panel and a third meeting involving the entire Supplier Systems and Relationships Focus Group: (1) Meeting on January 25-26, 1995 at El Segundo, California hosted by Hughes Aircraft Company; (2) meeting on February 22-23, 1995 at MIT, hosted by the Lean Aircraft Initiative; and (3) the Focus Group Workshop on April 4-5, 1995 at MIT, hosted by the Lean Aircraft Initiative. A list of the participating members at all three meetings is appended.

These preliminary results build upon prior research conducted under the auspices of MIT's International Motor Vehicle Program (IMVP) and draw upon a survey of the aircraft industry conducted by the Supplier Systems and Relationships Focus Group of the Lean Aircraft Initiative at MIT. A copy of an earlier document summarizing key characteristics of supplier systems and relationships in the worldwide automobile industry, based on previous IMVP research, can be obtained from the author.

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SUMMARY OF OVERARCHING PRACTICES AND METRICS

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Overarching Practices		Potential Metrics (Illustrative)
1.0.0	**Proactive planning, integration and management of supplier network** *Definition*: Optimization of size and structure of supplier network, based on "make-buy" criteria reflecting the firm's core competence, in order to minimize cost, cycle time and process variability while ensuring supplier performance and reliability.	• Cost to spend/place a purchasing dollar • Number of direct production suppliers • Percent of suppliers selected on basis of "best value"
2.0.0	**Early and substantial involvement of suppliers in design and development (including concept exploration and definition, demonstration and validation, engineering and manufacturing development, and production phases)** *Definition*: Delegating to key selected suppliers the engineering, design, development and testing of major components previously designed and built in-house, as part of proactive top-level longer-term competitive strategic thrust to minimize cost (both production cost and transaction cost), reduce cycle time and improve quality.	• Design process cycle time; total engineering hours utilized (including those provided by suppliers) from requirements definition to first prototype (for most recent new or upgraded product) • Percent of the total number of parts/systems where suppliers either worked cooperatively with customer firm during design process or had total design responsibility to customer's performance requirements (by cost, in last three years) • Percent of parts/systems where customer firm retained design responsibility and involved suppliers for DFM, DFA and DFF

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Overarching Practices	Potential Metrics (Illustrative)
3.0.0 Mutually beneficial relationships *Definition:* Building long-term cooperative relationships with suppliers stressing extensive information-sharing and joint-problem solving, based on mutual trust and commitment.	• Percent of relationships where relationship is governed by long-term agreements • Percent of suppliers where interactions involve a high degree of information exchange, joint problem solving and mutual commitment • Percent of relationships where the basic relationship represents strategic alliances/partnerships
4.0.0 Synchronized production and delivery *Definition:* Coordination of production and delivery schedules in order to eliminate waste, minimize cost and cycle time, and maximize agility and responsiveness throughout the entire supplier network.	• Percent of all direct suppliers that are provided requirements forecasts in advance • Percent of shipments arriving on-time, delivered to point-of-use with no prior inspection by customer
5.0.0 Continuous cost reduction and quality improvement *Definition:* Continuous incremental cost reduction and quality improvement through joint action based on mutual sharing of benefits.	• Average annual percent reduction in real unit cost (for major suppliers) over last three years • Percent of process/product improvements at customer company based on innovations originating at supplier company

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1.0.0 Overarching Practices **1.1.0 Enabling Practices** **1.1.1.0 Supporting Practices** **1.1.1.1 Operating Practices**	**Potential Metrics (Illustrative)**
1.0.0 Proactive planning, integration and management of supplier network *Definition*: Optimization of size and structure of supplier network, based on "make-buy" criteria reflecting the firm's core competence, in order to minimize cost, cycle time and process variability while ensuring supplier performance and reliability.	• Number of direct production suppliers (includes contract assembly) • Cost to spend/place a purchasing dollar; cost of supply chain management (encompassing cost of quality) as percent of total purchasing dollar spent; subcontracting cycle time (from requirements to placement); cost per transaction • Firm (business unit) performance (cost/price; cycle time/schedule/delivery; quality/defects); competitive advantage (e.g., market share, firm profitability)
1.1.0 Size and structure of supplier network linked to corporate competitive strategy	• Outsourcing dollars as percent of output • Percent of outsourcing dollars explicitly based on "make-buy" criteria tied to firm's competitive strategy
1.2.0 Integrating internal organization for supply chain management; move from transactions to strategic management in internal supply chain management activities	• Personnel engaged in supply chain management activities as percent of total business unit employment • Percent of supply chain management personnel person-hours processing subcontracts/purchase orders below critical size; percent of total number of transactions below a critical dollar volume that are automated from order to payment • Number (%) of direct production suppliers common to all business units of company • Average cycle time for subcontracting awards
1.2.1 Training of personnel engaged in supply chain management activities/decisions toward building strategic supplier alliances	• Number of hours of formal training provided to internal personnel engaged in supply chain management activities
1.3.0 Supplier selection based on prior performance	• Percent of suppliers selected on basis of "best value" contracting, based on price and other performance factors

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1.0.0 Overarching Practices **1.1.0 Enabling Practices** **1.1.1.0 Supporting Practices** **1.1.1.1 Operating Practices**	**Potential Metrics (Illustrative)**
1.3.1 Supplier performance evaluation (on-going process)	• Percent of suppliers for which a formal performance rating system is in place; percent of suppliers that are certified
1.3.2 Supplier selection on the basis of past relationships and proven performance; "two supplier" policy sector dependent	• Past performance (price, quality, delivery)
1.4.0 Key suppliers delegated production of major parts/components/systems (i.e., Key suppliers given esponsibility for the assembly/subassembly or anufacturing of major parts, components and systems, here they may or may not be responsible for design and /here they are delegated the production of more and more omplex parts/components/systems.)	• Percent of suppliers responsible for production of major components/subsystems • Percent of major components/subsystems which are delegated to suppliers for production
1.5.0 Proactive vertical coordination of supplier network	• Percent of shipments received on time (contract or need basis)
1.5.1 Supplier development (e.g., providing strategic resources to suppliers, such as materiel, technology, training)	• Average number of hours of technical training provided to key suppliers (prime to first-tier, first-tier to second-tier, etc.) • Size of the supplier development personnel (relative to total number of unique parts obtained from suppliers) • Percent of suppliers receiving customer's production schedule • Number of hours per year across suppliers (in same tier) involving technical information sharing and process/product improvement methods
1.5.2 Management of supplier clusters by first-tier or second-tier suppliers, not by the prime	• Percent of subtier suppliers directly interacting with prime • Percent first-tier and second-tier suppliers
1.5.3 Industry associations used for rapid information sharing and technology transfer to improve quality throughout supplier network	• Percent of suppliers actively participating in industry associations aimed at technology transfer and quality improvement

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1.0.0 Overarching Practices **1.1.0 Enabling Practices** **1.1.1.0 Supporting Practices** **1.1.1.1 Operating Practices**	**Potential Metrics (Illustrative)**
2.0.0 Early and substantial involvement of suppliers in design and development (including concept exploration and definition, demonstration and validation, engineering and manufacturing development, and production phases) *Definition*: Delegating to key selected suppliers the engineering, design, development and testing of major components previously designed and built in-house, as part of proactive top-level longer-term competitive strategic thrust to minimize cost (both production cost and transaction cost), reduce cycle time and improve quality.	• Design process cycle time; total engineering hours utilized (including those provided by suppliers) from requirements definition to first prototype (for most recent new or upgraded product) • Percent of the total number of parts/systems where suppliers either worked cooperatively with customer firm during design process or had total design responsibility to customer's performance requirement (by cost, in last three years)
2.1.0 Where design and /or build responsibility is retained in-house, involve suppliers for DFM, DFA, DFF	• Percent of the total number of parts/system where customer firm has retained design responsibility and involved suppliers for DFM, DFA, DFF (by cost, in last three years) • Supplier process capability in critical processes • Design process cycle time • Producibility; compatibility for integration and assembly (e.g., deviation from design goals)
2.1.1 Increase utilization of standardized design (use/reuse) and minimize number of unique parts for a given product	• Percent of engineering design content consisting of use of standardized designs; unique parts as percent of total number of parts
2.1.2 Utilize design approaches requiring minimum tooling or calling for reconfigurable tooling in order to minimize model/variety change over time (cost)	• Model/variety changeover time (for most recent product)
2.2.0 Involve subcontractors in collaborative design approach	• Percent of the total number of parts/system designed in collaboration with suppliers (by cost, in last three years)

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1.0.0 Overarching Practices **1.1.0 Enabling Practices** **1.1.1.0 Supporting Practices** **1.1.1.1 Operating Practices**	**Potential Metrics (Illustrative)**
2.2.1 Select key direct (first-tier) suppliers at the concept exploration and definition proposal stage of the product design and development process	• Percent of suppliers responsible for design and development for major parts/components systems
2.2.2 Use electronic commerce (both technical and business systems)	• Percent of direct production suppliers having electronic commerce capabilities for design and development and communication
2.2.3 Use multidisciplinary customer-supplier teams	• Percent of parts/systems designed by using integrated customer-supplier teams
2.3.0 Delegate design to suppliers to customer's performance requirements (in conjunction with practice of "target costing")	• Percent of "black box" parts/systems designed and developed by suppliers to customer's performance requirements (by cost, in last three years)
2.3.1 Government provides clear requirements and expectations to the prime; the prime (customer company) provides clear requirements and expectations to subcontractors/suppliers	• Number of requests for clarification (on engineering/drawing information provided to suppliers (e.g., in last year) • Number of TBDs in performance specifications or SOW • Number of directed changes • Design process cycle time
2.4.0 Customer firm focuses on critical (core) parts, components, systems or activities as part of a continuous "make-buy" strategy tied to core competence	• Dollar value of outsourcing of direct production material, parts components or systems as percent of total value of end-product output
3.0.0 Mutually beneficial relationships *Definition:* Building long-term cooperative relationships with suppliers stressing extensive information-sharing and joint-problem solving, based on mutual trust and commitment	• Percent of suppliers actively participating in industry associations aimed at technology transfer and quality improvement
3.1.0 Cooperative supplier relationships	• Percent of suppliers where the interactions involve a high degree of information exchange, joint problem solving, and mutual commitment

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1.0.0 Overarching Practices **1.1.0 Enabling Practices** **1.1.1.0 Supporting Practices** **1.1.1.1 Operating Practices**	**Potential Metrics (Illustrative)**
3.1.1 Extensive information exchange and mutual commitment; "voice" type of relationship [Helper, 1987,1991,1993,1994]	• Frequency of interactions (e.g., visits) involving technical information exchange
3.1.1.1 Suppliers providing customers detailed information on process steps, SPC charts, costs, supply sources, production schedules	• Type and frequency of information exchange (from supplier to customer)
3.1.1.2 Customers providing suppliers non-public financial information, technical training, requirements forecasting	• Type and frequency of information exchange (from customer to supplier)
3.1.1.3 Frequent exchange of information (formal and informal) via mutual visits, face-to-face meetings, electronic commerce	• Type and frequency of technical and management interaction (two-way exchange)
3.1.1.4 Greater use of information technologies to achieve coordination of a wide range of functions (e.g., purchasing, engineering, production control, quality, transportation, payment)	• Percent of all subcontracts and purchase orders placed electronically
3.1.2 Joint problem-solving to trace problems to their ultimate source; conflict resolution through negotiation and mutual accommodation [Reference: "Factory Operations Lean Practices, Enablers and Metrics in the Defense Aircraft Industry," March 17, 1995, Overarching Practice 9.0.0]	• Type frequency, method and purpose of interaction (e.g., joint diagnosis and resolution of technical problems)

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3.1.3 Progressively growing mutual interdependence; high "switching costs" (e.g., Delegation of responsibility to suppliers for designing, testing and producing more and more complex parts/components)	• Percent (by value) of end-product value outsourced from direct production suppliers
3.1.4 Relation-specific investment in suppliers (expertise, equipment, R&D)	• Type and amount of relation-specific investments in suppliers
3.1.5 Strategic supplier alliances and partnerships (Establishing strategic alliances with suppliers [formal or informal], involving joint ventures, cross-licensing, R&D partnerships, consortia, equity shareholding)	• Percent of suppliers (customers) where the basic relationship represents strategic alliances and partnerships • Time-to-market; design-to-cost; percent of suppliers where the basic relationship involves risk-sharing and/or cost-sharing
3.1.6 Use "best value" oversight process for industry and government – Recognize, reward, share and disseminate improvements in oversight process	• Percent of contracts/subcontractors awarded on a "best value" contract basis • Percent of suppliers with which customer has gainsharing arrangements
3.2.0 Long-term stable relationships	• Average length of supplier contracts with major critical suppliers
3.2.1 Long-term purchase agreements (Top level strategic planning and management by product commodity categories)	• Percent of total dollar value of outsourcing to suppliers under long-term agreements • Percent of suppliers with which customer company has long-term purchase agreements (implicit, explicit)

1.0.0 Overarching Practices **1.1.0 Enabling Practices** **1.1.1.0 Supporting Practices** **1.1.1.1 Operating Practices**	**Potential Metrics (Illustrative)**
3.2.2 Long-term commitment to mutual continuous improvement - Stress on trust-building behavior through actions displaying "visible" and "gradual" commitment, establishing "norms for proper behavior and "investment in reputation [Smitka, 1991, pp. 162-174]	• Profitability of suppliers • Cost of doing business with customers • Supplier assessment of customer commitment: High probability that supplier will do business with same customer (expected number of years) [Helper and Sako, 1994, Fig.2]
4.0.0 Synchronized production and delivery *Definition:* Coordination of production and delivery schedules in order to eliminate waste, minimize cost and cycle time, and maximize agility and responsiveness throughout the entire supplier network	• Percent of shipments arriving on time, delivered to point-of-use with no prior inspection by customer company (JIT) • Number of linestops due to stockouts
4.1.0 Support optimization of supplier process flows and throughput in concert with factory operations lean practices [Reference: "Factory Operations Lean Practices, Enablers and Metrics in the Defense Aircraft Industry," March 17, 1995, Overarching Practice 5.0.0]	• Flow time expressed in days, weeks, or months to complete a given product once introduced into the factory operation
4.2.0 Flexible production capability	• Measures of flexibility (volume, mix, product variation, model change, next generation product development) Example: Average tooling to handle multiple tasks
4.2.1 Customer and supplier build capability for flexible production systems to accommodate rapid changes in volume, mix, product variation, model change and next generation product development	• Specific measures of flexibility (e.g., use of flexible tooling to handle multiple tasks)

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4.3.0 Just-in-time (JIT) production and delivery system	• Percent of shipments of all direct production materials, parts and components arriving on time
4.3.1 Customer/supplier capability to produce parts in order to meet JIT requirements involving frequent delivery of smaller batches of parts to assembler and to minimize the amount of inventory held to support the factory operation [Reference : "Factory Operations Lean Practices, Enablers and Metrics in the Defense Aircraft Industry," March 17, 1995, Overarching Practice 6.0.0]	• Supplier lead time from order to delivery for one or more products • Percent of all shipments of multiple products produced by supplier delivered to respective customers on time • Dollar value of in-process inventory measured in terms of number of factory running hours (manufacturing, assembly) required to produce it
4.3.2 Customers providing suppliers with requirements forecasts in advance using information technologies	• Percent of all direct production suppliers that are provided requirements forecasts in advance using information technologies
4.3.3 Suppliers deliver parts directly to point-of-use	• Percent of all direct production materials, parts and components delivered directly to point-of-use
4.3.4 Integration of transportation and logistics management	• Percent of all direct production materials, parts and components handled by suppliers or third-party providers of integrated logistics services
4.3.5 No prior source inspection or testing by customer	• Percent of all incoming shipments from suppliers receiving source or incoming inspection/testing by customer
4.3.6 Minimize the level (size) of inventories	• Value of finished goods inventories as percent of value of output • Value of work-in-progress inventories as percent of value of output • Value of all inventories as percent of value of output

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5.0.0 Continuous cost reduction and quality improvement *Definition:* Continuous incremental cost reduction and quality improvement through joint action based on mutual sharing of benefits.	• Average annual percent reduction in real (inflation adjusted) unit costs over the last three years • Total product defect (reject) rate
5.1.0 Establishing prices and analyzing costs by stage of production, by identifying each factor that could lower cost of each part, component or system through Value Engineering (VE) process using "target costing"	• Percent of suppliers involved in target costing practice with customer company where the jointly established targets are achieved
5.1.1 Jointly break down costs by stage of production and identify each factor that could lower cost of each part, component or system through Value Engineering (VE) process using "target costing"	• Percent of suppliers involved in target costing practice with customer company where the jointly established targets are achieved
5.1.2 Mutual negotiation on how to reach the target and still allow reasonable profit for supplier	• Rate at which unit prices are continually declining over the length of a production "block" or model for the end-product
5.1.3 Value analysis (VA) to achieve further cost reductions once part, component or system is in production (on-going process)	• Percent of process or product improvements at customer company based on innovations originating at suppliers
5.2.0 Mutual sharing of cost savings (where supplier-derived cost savings beyond agreed upon targets accrue to supplier to induce suppliers to innovate (virtuous circle of cooperation")	• Percent of process or product improvements at customer company based on innovations originating at suppliers
5.2.1 Government incentives to primes and suppliers for continuous cost reduction and quality improvement allowing for gainsharing arrangements	• Gainsharing arrangements (e.g., analogous to incentive rate of regulation practices in utility industry)

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5.2.2 Prime-to-supplier incentives for continuous cost reduction and quality improvement (e.g., incentivize suppliers to recommend and implement methods to reduce flowdowns resulting in cost savings and quality improvement	• Use of explicit gainsharing arrangements
5.3.0 Strive for zero defects through mutual problem-solving and quality improvement, focusing on key product and process characteristics	• Percent improvement in supplier process capability for critical processes (direct production suppliers) • Defect rate (in-house)
5.3.1 Help build supplier capability by providing technical and training assistance (SPC, failure analysis, design of experiments)	• Duration and frequency of on-site technical assistance and training to suppliers in such areas as SPC, failure analysis, and design of experiments
5.3.2 Continuous reduction in level of formal inspection tied to improved process capability	• Percent of all incoming shipments of direct production material, parts or components received at customer's facility with no prior inspection by customer • Percent of direct production suppliers empowered to perform inspection • Percent reduction in inspections performed by customer firm

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Participants at the January 25-26, 1995 Meeting **Hughes Aircraft Co.** **El Segundo, California**	**Participants at the February 22-23 Meeting** **Massachusetts Institute of Technology** **Cambridge, Massachusetts**	**Parcipants at the April 4-5, 1995 Meeting** **Massachusetts Institute of Technology** **Cambridge, Massachusetts**
• Rudy Bini, McDonnell Douglas Aerospace • Kirk Bozdogan, MIT • Cynthia Cook, Harvard University and MIT • Charles Davis, McDonnell Douglas Aerospace • Jim Gorman, Textron Defense Systems • Jack Harwell, Martin Marietta Electronics & Missiles • Mick Hitchcock, MANTECH, WPAFB, USAF • Jerry Hopp, Boeing Defense and Space Group • Joe Hubbard, GE Aircraft Engines • Kaye Husbands, Williams College and MIT • Frank Long, Hughes Aircraft • Bill McNeil, Westinghouse Electronic Systems • Lynne Pierce, Lockheed Aeronautical Systems Co. • George Reynolds, Westinghouse Electronic Systems • Stan Rich, Hughes Aircraft • Jim Struss, Rockwell International	• Rudy Bini, McDonnell Douglas Aerospace • Kirk Bozdogan, MIT • Kevin Brown, Pratt & Whitney • Cynthia Cook, Harvard University and MIT • Charles Davis, McDonnell Douglas Aerospace • Jim Gorman, Textron Defense Systems • Mick Hitchcock, MANTECH, WPAFB, USAF • Joe Hubbard, GE Aircraft Engines • George Reynolds, Westinghouse Electronic Systems • Jim Struss, Rockwell International	• Rudy Bini, McDonnell Douglas Aerospace • Kirk Bozdogan, MIT • Kelly Brown, USAF (F-22) SPO • Kevin Brown, Pratt & Whitney • Cynthia Cook, Harvard University and MIT • Charles Davis, McDonnell Douglas Aerospace • Mike DiLeo, Northrop/Grummon • Jim Gorman, Textron Defense Systems • LeRoy Haugh, AIA • Mick Hitchcock, MANTECH, WPAFB, USAF • Joe Hubbard, GE Aircraft Engines • Dick Kane, HQ DCMC • Kaye Husbands, Williams College and MIT • Frank Long, Hughes Aircraft • Sita Lowman, Texas Instruments • Wayne Mackey, Hughes Aircraft • David Nelms, Martin Marietta; Electronics and Missiles • Ron O'Daniell, HQ DCMC • Lynne Pierce, Lockheed Aeronautical Systems Co. • Barbara Reeves, Beech Aircraft • George Reynolds, Westinghouse Electronic Systems • Stan Rich, Hughes Aircraft

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		• Jim Struss, Rockwell International • Gary Thompson, Rockwell-Collins • Al Vaughan, Sundstrand • Mike Walters, Lockheed, Ft. Worth • Todd Watkins, Lehigh University