Executive Summary

The strategic community relies heavily on the Cobra Judy (CJ1) instrumentation to provide high-quality radar and telemetry data for ballistic missile system testing and development. The current CJ1 platform, USNS Observation Island (T-AGM 23), will be 50 years old in 2003, and the CJ1 system requires an upgrade in technology. This report investigates the feasibility of converting an existing ship to a Mobile Test Range Asset in order to field a platform carrying the Cobra Judy II (CJ2) system on a much newer ship. Based on a review of available hull forms and prior research, the Henry J. Kaiser class oiler (T-AO 187) was found to be the most suitable conversion candidate. All equipment pertaining to underway replenishment (UNREP) was removed and replaced with components of the CJ2 system. Additionally, systems to provide ballast and electrical power were evaluated and installed, as necessary. The Advanced Surface Ship Evaluation Tool (ASSET), Program of Ships Salvage and Engineering (POSSE), and Ship Wave Analysis (SWAN) software tools were used to evaluate the converted ship's general, structural/stability, and seakeeping characteristics, respectively. The MIT Cost Model was used to estimate conversion costs, excluding acquisition costs of CJ2 sensors. The following table summarizes the characteristics of the CJ2 ship conversion design.

CJ2 Conversion Design Summary	
LBP	650 ft
B	98 ft
T	31 ft
Full Load Displacement	35161 ltons
KG	32.6 ft
GMT/B	0.093
Max. Speed	20 knots
Range	9300 nm (at 15 kts)
Seakeeping	Operable in Sea State 5
Conversion Cost	179 MDol

Table of Contents

List of Figures

List of Tables

List of Appendices

List of Acronyms

AMR	Auxiliary Machinery Room
ASSET	Advanced Surface Ship Evaluation Tool
B	Beam
BHP	Brake Horsepower
CIWS	Close-In Weapons System
CJ (1,2)	Cobra Judy (1,2)
COO	Concept of Operations
C_P	Prismatic Coefficient
C_X	Maximum Section Coefficient
C_{WP}	Waterplane Coefficient
C^4ISR	Command, Control, Communications, Computer/Information, Sensor, Reconnaissance
DAB	Defense Acquisition Board
DDS	Design Data Sheet
D_0	Depth at Station 0
D_{10}	Depth at Station 10
EDG	Emergency Diesel Generator
EHP	Effective Horsepower
FAA	Federal Aviation Administration
FL	Full Load
GMT	Transverse Metacentric Height
HF	High Frequency
HSS	High Strength Steel
KG	Keel to Center of Gravity
LBP	Length Between Perpendiculars
LCC	Life Cycle Cost
LCG	Longitudinal Center of Gravity
LOS	Line of Sight
LS	Light Ship

MARAD	Maritime Administration
MDA	Missile Defense Agency
MIN OP	Minimum Operating
MIT/LL	Massachusetts Institute of Technology/Lincoln Laboratory
MMR	Main Machinery Room
MNS	Mission Needs Statement
MSC	Military Sealift Command
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
ORD	Operational Requirements Document
PDSS	Propulsion Derived Ship's Service
POSSE	Program of Ships Salvage and Engineering
ROC	Required Operational Capabilities
RSPS	Radar Service Power System
SATCOM	Satellite Communication
SHP	Shaft Horsepower
SSDG	Ship's Service Diesel Generator
STANAG	Standards of Agreement
SWAN	Ship Wave Analysis
SWBS	Ships Work Breakdown Structure
T	Draft
TSI	Tons per Square Inch
UHF	Ultra High Frequency
UNREP	Underway Replenishment
USNS	Unites States Naval Ship
VCG	Vertical Center of Gravity
VHF	Very High Frequency

1.0 Mission Need

1.1 Defense or National Guidance and Policy

The Mission Needs Statement (MNS) for the Cobra Judy II (CJ2) Mobile Test Range Asset is classified and not included in this document. However, the need for such a ship is addressed in part by the September 2001 Quadrennial Defense Review Report, which states: "Technologies for sensors, information processing, precision guidance, and many other areas are rapidly advancing... for the United States, the revolution in military affairs holds the potential to confer enormous advantages and to extend the current period of U.S. military superiority... exploiting the revolution in military affairs requires not only technological innovation but also development of operational concepts...."[1] The MNS should be used to guide CJ2 design, research, development, and cooperative efforts with U.S. Allies. Based on the MNS guidance and policy, the CJ2 must provide support for interagency, joint, and Allied forces, as well as aid in the development and testing of technologies pertinent to ballistic missile systems.

1.2 Threat Analysis

As a non-combatant, there are no direct threats to CJ2.

1.3 Current Capability Assessment

The existing data collection platform, the USNS Observation Island (T-AGM 23), was originally launched in 1953 and converted to an instrumentation radar platform in 1981. The ship is nearing the end of useful service life, and the Cobra Judy I (CJ1) data collection system onboard Observation Island does not meet projected requirements for data collection and radar testing.

1.4 Mission Needs

The MNS for CJ2 is classified and is not included in this document. A need exists for a Mobile Test Range Sensor to collect ballistic missile data in order to evaluate missile target characteristics and in-flight behavior.

1.5 Recommended Alternatives

Alternative concepts included in the MNS are airborne platforms and sensors, space-based platforms and sensors, and land-based sensors. The sea-based platform provides the desired flexibility and minimizes cost. Alternative sea-based concepts include conversion of an active ship, new ship construction, or towed platform.

1.6 Results of Milestone 0 Defense Acquisition Board (DAB)

Verbal approval to explore the conversion concept was received on January 15, 2002.

2.0 Design Requirements and Plan

2.1 Required Operational Capability

There is no existing Operational Requirements Document (ORD) for CJ2. The Required Operational Capabilities (ROC) are based on verbal guidance given by the sponsors of this ship conversion. Table 1 lists these ROCs.

Table 1. CJ2 Required Operational Capabilities

ROC	Description
1	Provide own unit's C4I functions
2	Conduct Sensor and ECM operations
3	Conduct intelligence collection
4	Steam to design capability in most fuel efficient manner
5	Prevent and control damage
6	Perform seamanship, airmanship and navigation tasks (navigate, anchor, mooring, scuttle, life boat/raft capacity, tow/be-towed)
7	Replenish at sea
8	Maintain health and well-being of crew
9	Provide upkeep and maintenance of own unit

2.2 Concept of Operations/Operational Scenarios

The CJ2 Concept of Operations (COO) is based on the expected CJ2 mission needs and existing CJ1 operating characteristics. The notional composite scenario is outlined in Table 2.

Table 2. Notional Composite Scenario

Day 1-10	Transit to Operational Area 1
Day 11-18	Conduct on-station monitoring as required
Day 19-28	Transit to Operational Area 2
Day 29-36	Monitor US missile testing
Day 36-50	Respond to urgent tasking, transit to Operational Area 3 for on-station monitoring, UNREP during transit
Day 51-60	Return to Base

2.3 Goals, Thresholds, Constraints, Standards

As there is no ORD issued for CJ2, no goals, thresholds, or constraints were available for use at the time of this writing. Also, due to classification requirements, the operational capabilities of the radar systems cannot be included in this report. Nominal ship operational capabilities of CJ2 are summarized in Table 3.

Table 3. Nominal Ship Operating Characteristics

Maximum Speed	20 knots
Endurance Speed	15 knots
Endurance Range	10000 nm
Endurance Stores	60 days
Seakeeping	Operational in Sea State 5

The following standards were used in the development of this conversion design:

- General Specifications for Ships of the United States Navy, NAVSEA s(AA0-AA-SPN-010/Gen-Spec)
- Structural Strength: DDS 100-1,2,4,5,6,7
- Stability and Buoyancy: DDS 079-1
- Freeboard: DDS 079-2
- Powering: DDS 200-1, 310-1.

2.4 Design Philosophy

The goal of this conversion design was to determine the most suitable platform for the CJ2 data collection system while minimizing Life Cycle Cost (LCC). Generally, the required equipment modifications were performed in order to minimize impact to the existing ship. Specifically, equipment was retired in-place, when possible, and diesel propulsion was used to maximize fuel efficiency and reduce manning requirements. Also, major upgrades to the existing ship, such as the CJ2 system and electrical generators, were performed solely on the basis of need. Ultimately, the final design is capable of undergoing future expansion, as the use of removable ballast facilitates weight changes due to additional system upgrades.

3.0 Concept Exploration

3.1 Cobra Judy I Concept

The USNS Observation Island, shown in Figure 1, was originally built as a Mariner class merchant ship (C4-S-A1 type) in 1953.

Figure 1. USNS Observation Island (T-AGM 23)

The ship was acquired by the US Navy in 1956 and converted for use as a Fleet Ballistic Missile test ship. In 1972, it was placed in the Maritime Ready Reserve Fleet, where it spent seven years. In 1977, the Navy reacquired the ship from the Maritime Administration (MARAD) and transferred it to the Military Sealift Command (MSC). The ship, which was converted to a Missile Range Instrumentation Ship in 1981, carries the Cobra Judy (CJ) ship-borne phased-array radar system for collection of data on foreign ballistic missile tests. The US Navy operates the ship for the US Air Force Intelligence Command.[2]

Currently, the CJ Program provides worldwide high-quality, high-resolution, multi-wavelength radar and telemetry data to the Strategic Community, Missile Defense Agency (MDA), and related communities. The instrumentation aboard the Observation

Island includes an S-band phased-array radar, an X-band dish radar, a fully capable telemetry system, and various support systems. The S-band phased-array radar is the primary acquisition sensor onboard and is capable of tracking and collecting data on all objects in a multi-target complex. The X-band single-beam radar is a very high-resolution system that can be designated to an object in track by the S-band radar or an object that is not in S-band track via an external cueing source. Wideband data from the X-band has approximately a four-fold increase in resolution over the S-band. Both systems have multiple waveforms and bandwidths providing data collection flexibility to suit the user's needs. The telemetry system onboard covers the VHF to Ka-band frequency range. Steerable antennas may be directed manually or slaved to radar tracks.[3]

CJ’s mobility provides the flexibility needed to best match specific mission needs with the capabilities of the ship’s sensor suite. It has collected data on all phases of missile flight, including boost, post-boost, mid-course, and terminal phases. The ship has also been involved with aircraft and space imaging. Possible future missions include collecting weather radar data for the Federal Aviation Administration (FAA), evaluating metric and satellite reentry phenomenology, and mapping space debris for the National Aeronautics and Space Administration (NASA).[4]

CJ has been working with test ranges since its initial operational testing in 1982 and has experience working with most of the major ranges, including the Eastern Range, the Western Range, the Wallops Flight Facility, White Sands Missile Range, Pacific Missile Range Facility, and the Kwajalein Missile Range. An integral component of domestic missile testing, the Observation Island has a full communications suite, including HF, VHF line-of-sight (LOS), UHF LOS, and UHF Satellite Communication (SATCOM).[5]

3.2 Ship Selection Methodology

An initial search for a ship conversion candidate was conducted based on the criteria given in Table 3. Table 4 summarizes the suitable hulls found based on a search of the Navy’s active and inactive registers.

Table 4. Summary of Initial Search

Ship Type	Displacement (ltons)	Propulsion
Mariner Class Merchant	17015 (FL)	Steam
T-AO 187 (Henry J. Kaiser)	17000 (LS) 40700 (FL)	Diesel
LCC 19 (Blue Ridge)	18400 (FL)	Steam
LSD 41 (Whidbey Island)	15700 (FL)	Diesel
AOE 6 (Supply)	19700 (LS) 49000 (FL)	Gas Turbine

MIT Lincoln Laboratory (MIT/LL) performed prior research to determine a suitable conversion hull for a Mobile Range Sensor having systems similar to CJ2. The following hull types were not considered:

- All ships in hull type greater than 24 years old
- All ships in hull type eliminated or disposed
- Amphibious Assault Ships (LHDs and LHAs)
- Ocean Fleet Tugs.

Of the 16 hull types (450 ships) that remained, the following ships were eliminated:

- Ships assigned to USN or MSC Active Fleet, Army Combat Preposition Force, Logistics Prepositioning Ships, Marine Prepositioning Force
- Ships leased to universities or institutes
- Newly constructed ships (including ships under construction)
- Ships less than 300 ft in length
- Remaining ships with greater than 23 years of service

Of the seven hull types remaining, the Kaiser Class oiler (T-AO 187) was chosen for the following reasons:

- Lowest cost ships to modify and operate
- Adequate berthing for mission crew in place
- Adequate mission space below deck
- Approximately 5 MW of spare power available after fuel pumps removed
- Large amount deck space available for antennas
- Ships are 16 years old or less. [6]

Although the T-AO 187 hull appears to be an ideal conversion candidate, there are some issues of concern. The ship is much larger than required; after conversion, there will be a large amount of excess weight (in the form of ballast) and space. More importantly, the first ship in the class has exhibited excessive vibrations at high speeds. Although the CJ2 mission is based on operating at low speeds (3-5 knots), higher speeds are required for transit. Details on the effects of these vibrations were not available at the time of this writing. However, based on the fact that the T-AO 187 class oilers are considered the workhorse of the fleet, there appear to be no pressing concerns about reliability of follow-on ships. Regardless, the source and effects of these vibrations must be determined, regardless of conversion prospects.

Based on the available information, the T-AO 187 class oiler was chosen as the conversion hull. Currently, there are four Kaiser class oilers available for use. Table 5 lists these ships and addresses their suitability.

Table 5. Kaiser Class Oilers Available

Ship	Location	Remarks
Joshua Humphreys (T-AO 188)	***NISMF Philadelphia***	Good condition, only in service for five years
Andrew J. Higgins (T-AO 190)	MARAD Suisan Bay	Faulty propeller, needs replacement (approx. 5 MDol)
Benjamin Isherwood (T-AO 191)	James River	Construction incomplete
Henry Eckford (T-AO 192)	James River	Construction incomplete

Of the four hulls, the Joshua Humphreys is the desired choice, as no repair or construction work other than conversion would be required.[7]

3.3 Henry J. Kaiser Class Oiler Description

Table 6 summarizes the characteristics of a Kaiser class oiler, and Figure 2 shows a profile view of the ship.

Table 6. Kaiser Oiler Characteristics

LBP	650 ft
B	98 ft
T	35 ft
D_{10}	61 ft
Full Load Displacement	40700 ltons
Lightship Weight	14775 ltons
KG	31 ft
GMT/B	0.105
Maximum Speed	20 knots
Range	9100 nm (at 15 knots)
Crew Size	116

Figure 2. Henry J. Kaiser (T-AO 187)

The ship has a helicopter landing platform, carries the SLQ-25 Nixie torpedo decoy, is fitted for one CIWS mount, and can carry up to 180000 barrels of oil.

3.4 Ballast Options

Approximately 25000 ltons of cargo fuel can be carried by T-AO 187 at full load. In order to accommodate for the loss of this weight, the converted design must provide a suitable amount of ballast in order to ensure the ship meets structural and seakeeping requirements. Three types of ballast were considered for the design: water, lead, and commercial (Perma Ballast™). Each type of ballast is removable, permitting ease of future alteration. Table 7 describes some characteristics of each type of ballast material.

Table 7. Ballast Options

Ballast Material	Density (lb/ft^3)	Cost ($/lton)	Remarks
Water	62.4	Negligible	Corrosion, free surface
Perma Ballast™[8]	210/315	100/400	Extra space, roll period
Lead	710	>400	Extra space, roll period

Using water for ballast is by far the most inexpensive option. The main issues with water ballast are corrosion and free surface effects. In order to minimize corrosion, fresh water should be used, and some type of coating or paint must be applied to each tank during conversion and re-applied as necessary during the ship's life. Maintaining ballast tanks full during operation can minimize free surface effects.

Commercial ballast is composed of naturally occurring, nontoxic, noncorrosive, environmentally-safe materials and is available commercially. The commercial ballast considered for this conversion is Perma Ballast™, which is composed of inert minerals such as iron ore and is available from Ballast Technologies Inc. This option is cheaper than lead and takes up much less space than seawater ballast, which creates a large amount of arrangeable deck area for future use. However, as this type of ballast adds a large amount of weight low on the ship (reduces KG), the ship's roll period can be reduced significantly.

Lead ballast is typically placed on ships and submarines but is much more expensive than seawater or composite ballast. While lead may take up little space, it would likely be placed near the keel of the ship and have a negative effect on roll period.

Based on the seakeeping analysis, water ballast is the best choice, as the low KG realized with commercial and lead ballast reduces the roll period dramatically and results in poor seakeeping. The effects of the different ballast options will be discussed in detail in the structural analysis and seakeeping sections.

3.5 Final Concept Design

In order to accommodate the new mission requirements, all combat systems and equipment associated with UNREP were removed (or retired in-place) and replaced by CJ2 components. The CJ2 system is comprised of an S-band phased-array radar, an X-band phased-array radar, and two telemetry antennas. MIT/LL provided the weight and space requirements of the S-band and X-band systems, which are under contract to Lockheed-Martin and Raytheon, respectively. The telemetry information was provided by MIT/LL and was based on CJ1 telemetry systems. The exact capabilities and limitations of each system were unavailable for this report due to classification restrictions. Due to the excessive electrical power requirements of the CJ2 system, three additional diesel generators were placed on the ship. Table 8 summarizes the total weight removed from and added to the ship by Ships Work Breakdown Structure (SWBS).

Table 8. Weights Removed and Added by SWBS

SWBS Group		Weight Removed (ltons)	Weight Added (ltons)
100	Hull Structure	628.2	155.8
200	Propulsion Plant	15.2	0
300	Electric Plant	0	354.9
400	Command and Surveillance	7.1	188.4
500	Auxiliary Systems	383.2	29.6
600	Outfit and Furnishings	0	10.2
700	Armament	19.1	0
Total		**1052.8**	**738.9**

Therefore, after the conversion, the lightship weight was reduced by 313.9 ltons. The complete list of equipment removed is included in Appendix A. The complete list of equipment added, including CJ2 subsystems and electric power requirements, is included in Appendix B.

After making the above additions, the design was analyzed using ASSET, POSSE, and SWAN, then revised as necessary. Table 9 summarizes the characteristics of the final concept design.

Table 9. Final Concept Design

LBP	650 ft
B	98 ft
T	31 ft
Full Load Displacement	35161 ltons
KG	32.6 ft
GMT/B	0.093
Max. Speed	20 kts
Range	9300 nm (at 15 kts)
Seakeeping	Operable in Sea State 5
Conversion Cost	179 MDol

4.0 Feasibility Study and Assessment

4.1 Design Definition

4.1.1 Ship Geometry

As there were no major changes made to the original hull form, the geometry of the ship is largely unchanged. Figure 3 shows the hull isometric view, and Table 10 summarizes the principal characteristics of the ship's geometry.

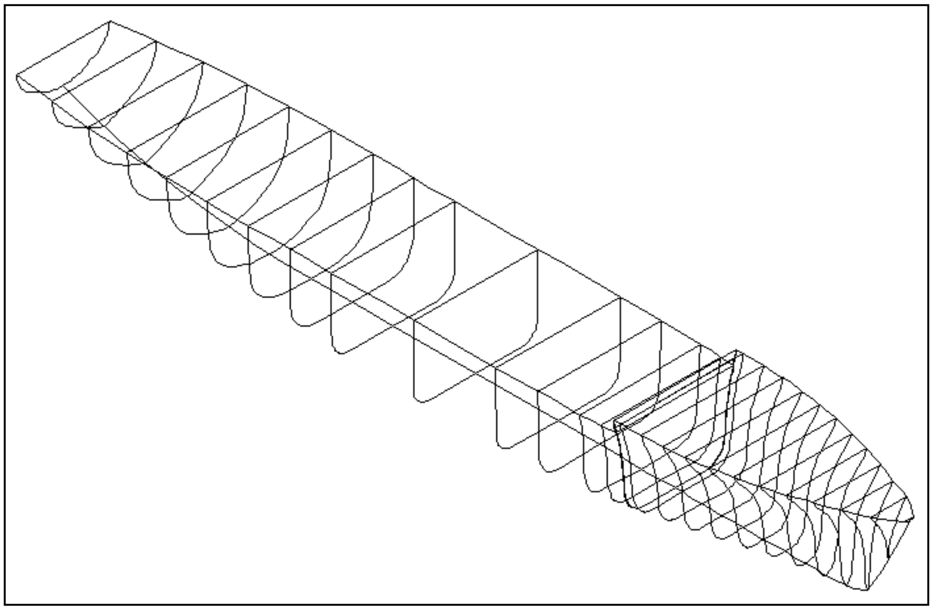

Figure 3. Hull Isometric View

Table 10. Principal Ship Geometry Characteristics

LBP	650 ft
B	97.7 ft
T	30.9 ft
Full Load Displacement	35161 ltons
D_0	70.8 ft
D_{10}	60.8 ft
Freeboard (station 0)	39.9 ft
C_P	0.65
C_X	0.98
C_{WP}	0.77
KG	32.6 ft
GMT/B	0.093

Figure 4 shows the body plan, and Figure 5 shows the curves of form.

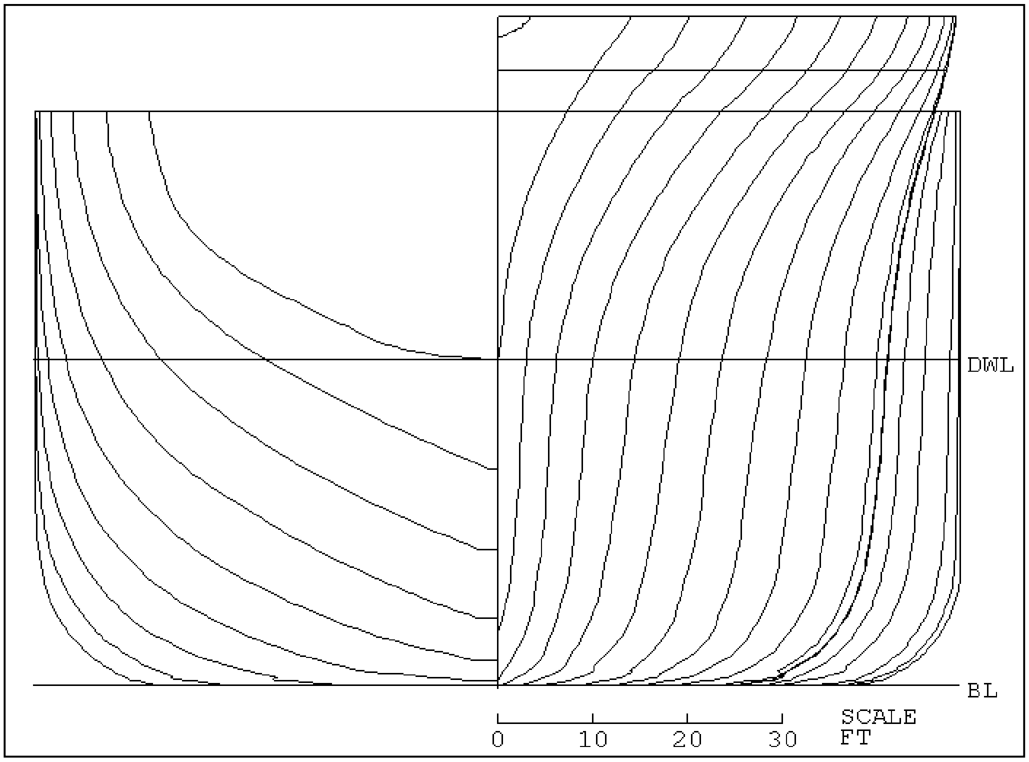

Figure 4. Body Plan

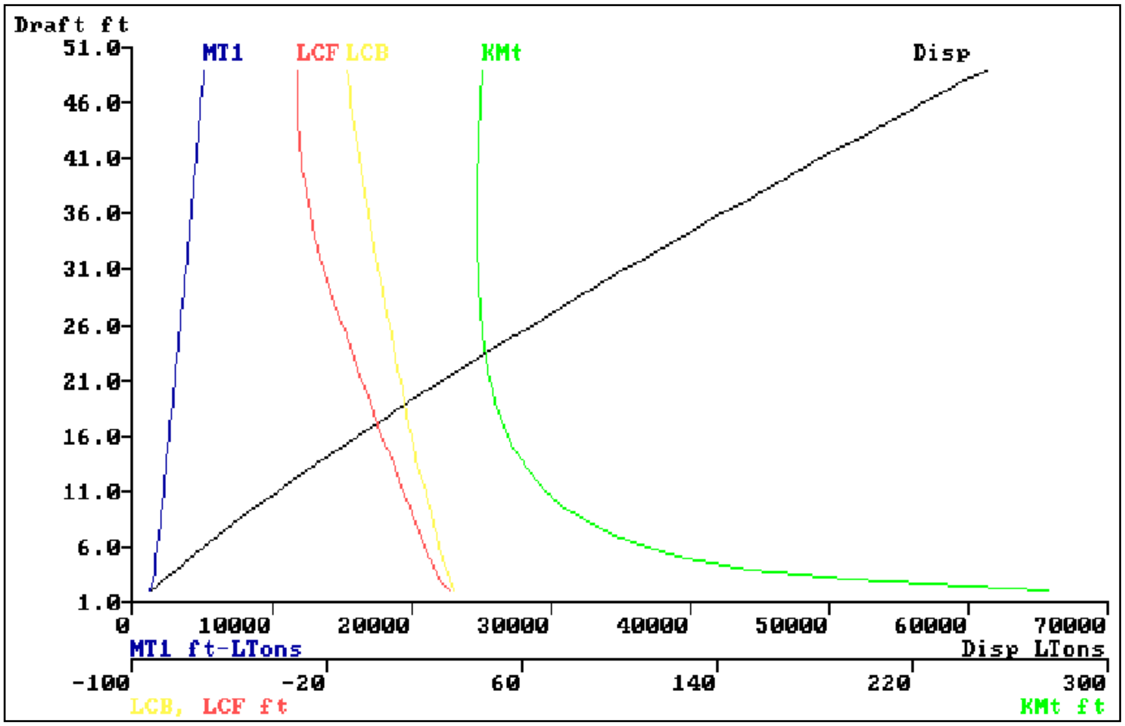

Figure 5. Curves of Form

4.1.2 C^4ISR/Mission Payload

Figure 6 shows the topside arrangement of the CJ2 data collection system.

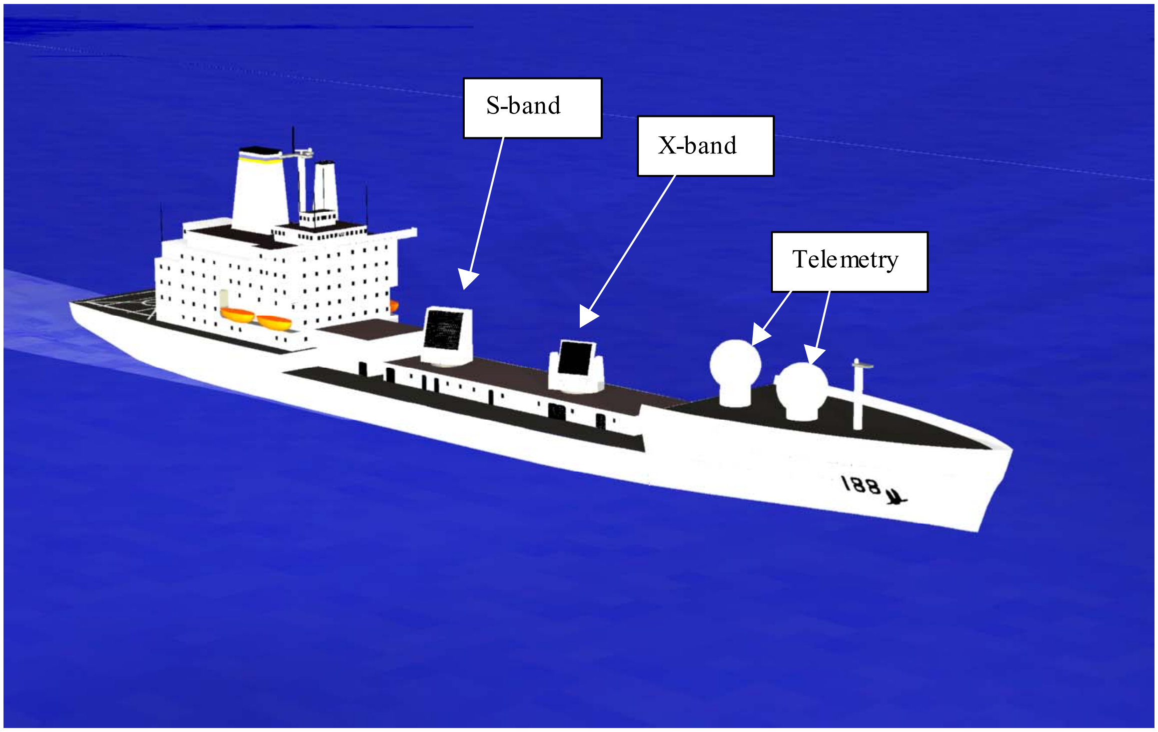

Figure 6. Topside Arrangement

The radars were placed amidships for stability purposes and to meet spacing requirements. All supporting radar equipment is placed in the deckhouse beneath the radars. The two telemetry dishes are placed on the forecastle. These dishes weigh much less than the radars and have little effect on the ship's weight distribution. However, the support spaces for the telemetry equipment are located on the main deck below the radars in order to minimize effects to personnel in high sea states. Also, the Radar Service Power System (RSPS) stack is located on the superstructure in order to minimize exhaust effects on the radars and telemetry systems.

4.1.3 Propulsion, Electrical, and Auxiliaries

No modifications were made to the existing ship propulsion plant. Figure 7 shows the general layout of the machinery spaces and major propulsion and electrical system machinery for CJ2.

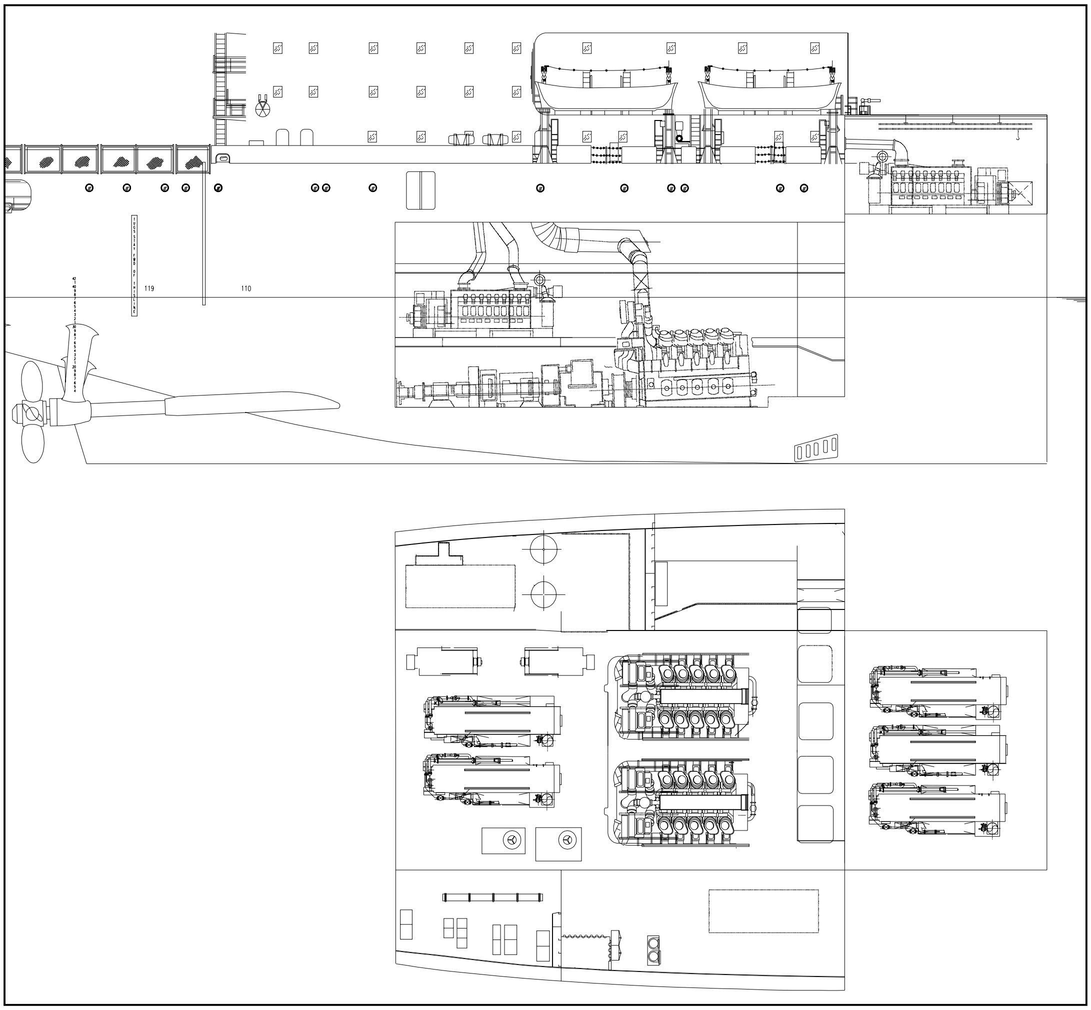

Figure 7. Machinery Space Layout

The propulsion plant for CJ2 consists of two Colt-Pielstick 10 PC4.2 V10 diesel main engines rated at 16,270 BHP each. The two main engines are located in the Main Machinery Room (MMR) and drive two shafts with 21-ft diameter controllable - reversible pitch propellers.

CJ2 has a calculated (ASSET) endurance range of 9100 nautical miles at 15 knots, which requires 1531 ltons of fuel. This is a conservative analysis as it considers that the radar power system is running at all times. If the CJ2 radars are secured during transit times, as expected, the achievable range will increase toward the goal value of 10000 nm. One method to increase range is to convert an existing cargo tank into a ship's service fuel tank. However, this option was not analyzed in detail due to the complexity of piping arrangements required. The range vs. speed curve is included in Appendix C.

The maximum speed of CJ2 is 20 knots with a sustained speed of 18 knots. At sustained speed the main engines are at 80% of rated power. Figure 8 shows the EHP vs. speed curve. The resistance vs. speed curve is included in Appendix C.

Figure 8. EHP vs. Speed

The ship's service electrical distribution system consists of two Ship's Service Diesel Generators (SSDGs), two Propulsion Derived Ship Service (PDSS) generators, and one emergency diesel generator (EDG). The two SSDGs are Caterpillar 3608 IL8 diesel generators, rated at 2500 kWe each. Both SSDGs are in the Auxiliary Machinery Room (AMR), which is just aft of the MMR. The two 2500 kWe PDSS generators are driven by power takeoffs from the main engines. These generators provide limited generating capacity at slow ship speeds and were disregarded in generating capacity calculations for the conversion. However, they can be used as main propulsion motors at slow speed, with the SSDGs providing electrical power to the ship and providing limited propulsion power. This lineup eliminates the need to operate the medium speed diesel main engines in off-design, inefficient ranges. During transit, the PDSS generators can be used for ship service needs as the higher speed enables more efficient operation; this arrangement also allows for maintenance of the SSDGs. Finally, a single 500 kWe Diesel Generator located in the upper section of the deckhouse provides emergency power when necessary.

In order to meet power requirements for the CJ2 instrumentation suite, three additional Caterpillar 3608 generators were placed just forward of the deckhouse to provide dedicated power to the radar systems. These generators, classified as the Radar Service Power System (RSPS), provide 7.5 MWe of 60 Hz AC power, which can be converted to DC or 400 Hz AC as necessary for the radars. The specific 400 Hz power requirements for the CJ2 system were unavailable at the time of this writing.

Electrical requirements were analyzed in some detail in order to determine if an independent power supply was required for the CJ2 system. The major reason for an independent RSPS is that the ship's service electrical system, though capable of supplying 10 MWe under optimal conditions, will not be able to provide the approximately 4 MWe of power required for the CJ2 system during operation. The CJ2 instrumentation will only be operated when the ship is on station, loitering at approximately 3-5 knots. The PDSS generators were designed to operate between 70% and 100% of rated speed, with reduced capability between 60% and 70%. As the ship normally provided UNREP services at speeds of 13 knots, the full 10 MWe was available. However, zero electrical output is available at less than 60% rated speed; thus, when loitering, only 5 MWe is available.[9] Therefore, for the conversion, only the 5 MWe from the SSDGs was considered to be available. As ship's service loads are less than 2500 kWe (after removal of the cargo pumps), these loads can be supplied from one SSDG, leaving the remaining SSDG available as needed for maintenance. As the CJ2 system requires almost 4 MWe for operation, three 2500 kWe RSPS generators are required for operation, two for normal loading and one for redundancy. Also, emergency connection of RSPS to the ship's service electrical system exists for emergency cross-connection of power. Figure 9 shows a general schematic of the electric plant.

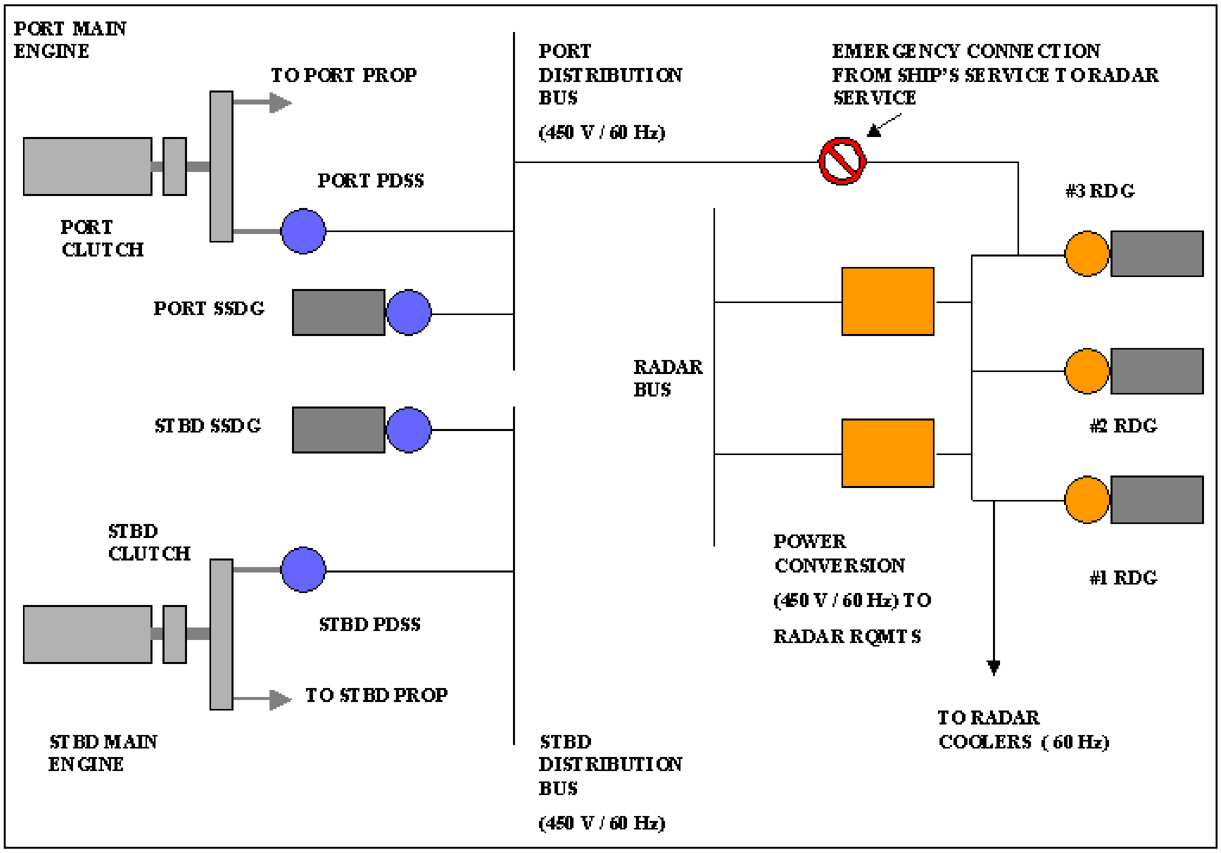

Figure 9. Electric Plant Schematic

The 24-hour electrical load for the ship is 2120 kWe with a maximum marginal load of 3000 kWe. The radar systems require approximately 3800 kWe of continuous power. Table 11 summarizes the electrical power removed and added during the conversion.

Table 11. Electrical Power Removed and Added

Item	Power (kWe)	System
Deletions		
Cargo Pumps	1975	Ship Service
Total Deleted	**1975**	
Additions		
X - Band Radar	1860	Radar Service
S - Band Radar	1860	Radar Service
Radar Cooling Units	500	Radar Service
Telemetry	50	Radar Service
Total RSPS Added	**4270**	

The auxiliary systems for CJ2 are all electric; therefore, no service steam is required for the ship. All UNREP gear and other oiler mission items were removed or retired in-place.

4.1.4 Survivability and Signatures

As the CJ2 is a noncombatant, the survivability and signatures of the ship are of little consequence and are not subject to naval design standards. The CJ2 has no need for signature reduction or self-defense capability other than small arms for security.

4.1.5 Manning

Some limited changes were made to the existing berthing arrangements. Table 12 summarizes the accommodations available on T-AO 187.

Table 12. Accommodations

Personnel	***Accommodations***
Officers	23
CPO	24
Other Enlisted	79
Total	**127**

MIT/LL projects that the approximate manning required for CJ2 will be 30 members for ship's force and 40 CJ2 technicians. Therefore, the current accommodations are more than satisfactory for CJ2. Based on these estimates, twelve staterooms were eliminated and converted for use as exhaust spaces for the RSPS diesel generators.

4.1.6 Arrangement

Prior to arranging the CJ2 mission equipment, existing T-AO 187 equipment was removed or relocated. First, the 01-level was razed between the forecastle and the superstructure. This section is approximately 270 feet in length and included UNREP equipment, kingposts, and a small deckhouse. Next, all UNREP equipment and deckhouses were removed from the main deck between the forecastle and superstructure. However, tank shore connections and access hatches were retired in place. All mooring, safety (excluding rescue boats), navigation, lighting, and embarkation equipment was either retained or relocated. The cargo loading and discharge systems were retired in-place in order to preserve as much previous mission capability as possible and minimize costs. A complete list of the equipment selected for removal or relocation is provided in Appendix A.

Figure 10 shows the major CJ2 equipment added to the ship as part of the conversion.

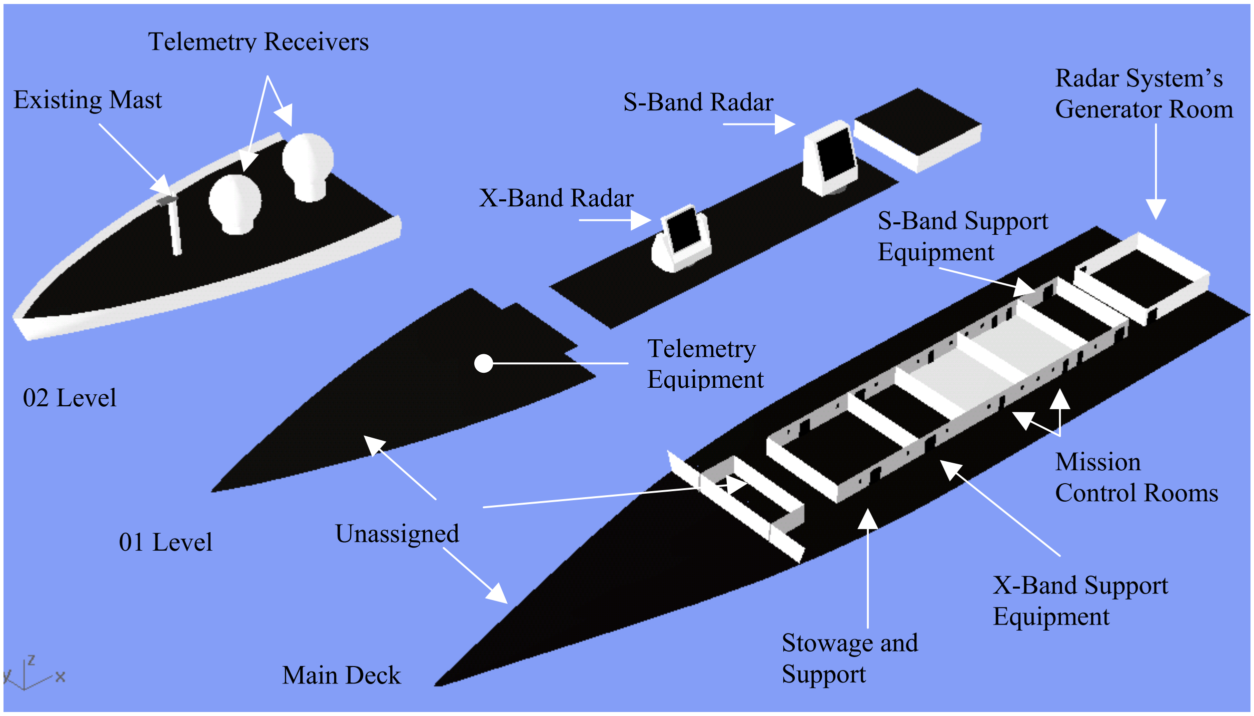

Figure 10. CJ2 Mission Equipment

Detailed General Arrangement (GA) drawings are included in Appendix D. The outboard profile, inboard profile, superstructure, main deck, 01-level, and 02-level deck plans from before and after conversion are included for comparison. Changes to the superstructure and decks below the main deck had minimal impact on the conversion. The following discussion on arrangement describes the changes made to the forecastle, mission section, and superstructure.

The conversion had little impact on the forecastle of the ship. All T-AO 187 stowage areas are unassigned spaces on the converted ship and can be used to meet future requirements. The 01-level Forklift Shop was converted to a telemetry systems equipment room, and the two telemetry receiver dishes and domes were placed centerline, aft, on the 02-level, as depicted in the GAs. This necessitated moving a vent house slightly aft, but otherwise the conversion resulted in minimal changes to the forecastle. Existing ground tackle and lights, including the forward mast, were not affected.

Two areas requiring further research are the addition of structural reinforcement under the telemetry receivers and the replacement of the forward mast with one more transparent to signals sent from and to the telemetry dishes. Additionally, the ship had two mounts for CIWS weapons, one on the bow and one aft of the bridge on the 06-level. As the CJ2 does not require these defensive weapons, their mounts were removed for the purposes of this conversion. A possible alternative is to retire the mounts and supporting equipment in-place in the event the ship needs them in the future.

The mission section is located between the forecastle and the superstructure. As mentioned previously, virtually all equipment was removed from the main deck and 01-level in this area. The GAs provided in Appendix D show all equipment removed and the new equipment added to the ship. The deckhouse containing the mission support and control equipment was placed in this section of the ship in order to minimize effects of seakeeping. As this section is close to the ship's center of gravity, relatively low motions will result from high sea states, maximizing equipment and personnel performance. The deck space in the forecastle is large enough to locate the mission section there, but the ship must be operable in sea state 5, so the amidships location is the best location. While placing the mission control systems in the forecastle may not prohibit mechanical operation of the systems, it would probably inhibit human operations.

As shown in Figure 10 above, the new deckhouse on the main deck in the mission section has five compartments. The forward-most compartment was designated for stores and support. This compartment also includes existing vent, access, and removal routes to the old cargo pumps, motors, and control room. As mentioned previously, this equipment will be retired in place; however, the old Cargo DFM Settling Tank will be converted to the compressor room for the radar cooling systems. Further detailed analysis is required to identify the specific cooling units to be used and the additional structural support needed these units, if necessary.

The second compartment on the main deck is the X-band radar equipment and support room, which contains all equipment necessary for operating and cooling the X-Band radar. This radar is located directly above this compartment on the 01-level. Future analysis is required to determine the structural modifications necessary to adequately support the radar

The next two compartments, the Mission Control Rooms, contain all operating and processing stations for the radar systems. As currently designed, these two compartments have elevated floors to provide wiring routes. The compartments have dropped acoustic tile ceilings and are cooled by ventilation systems in the adjacent radar support rooms. Two small spaces in the after mission control room will serve as quarterdeck offices while in port. These small offices do not have access to the mission control rooms. Lastly, this design retains the access hatches to the cargo tanks below the main deck. In the mission control rooms, these hatches' coamings should be altered to fit below the raised floor.

The last of the five compartments is the S-Band radar equipment and support room, which is similar to the X-Band radar equipment and support room. The S-Band radar is located above the bulkhead separating this compartment and the after mission control room.

A detailed structural analysis was not performed for this deckhouse arrangement, as the information necessary to determine the support structure needed for the radars was not available at the time this work was completed. It should be noted that the longitudinal and transverse bulkheads are in line with existing tank bulkheads below the main deck. The only exception to this is the aftermost transverse bulkhead of the deckhouse, which could not be sited above an existing tank transverse bulkhead because of the need for a break in the deckhouse for mooring lines. This should be considered in future structural evaluation of this conversion concept. The GAs do reflect the need for stiffened bulkheads and stanchions on centerline of the compartments.

Each of these five compartments has more than one access route to either the main deck or an adjoining compartment. Hatches do not separate the two mission compartments; however, there are airtight bulkheads and hatches between them and the adjacent radar equipment and support rooms. Additionally, the exterior bulkheads and hatches of the five main deck compartments should be watertight. Also, expansion joints must be incorporated into the radar deckhouse structure to reduce stresses and movement induced by hull bending and racking. Specifically, expansion joints were placed in the main radar deckhouse and the interconnecting passageways. The GAs in Appendix D show the locations of these joints.

The independent diesel generators for the RSPS were located just forward of the superstructure on the main deck. Initially, these generators were located in the old cargo pump and motor rooms, but a satisfactory method of venting the diesel exhaust could not be found. The hot exhaust cannot be vented forward of the radars because its exhaust and particulate accumulation would degrade radar performance. Additional concerns were exhaust exposure for bridge and deck personnel and accumulation of exhaust soot on the superstructure. One alternative was to use a wet exhaust system, but this method was assumed to be too expensive and complicated for such large diesels. Another alternative was to place them on a new flat in a former cargo tank, but this idea was also discarded due to concern over the length of exhaust uptakes necessary to run the exhaust above the 06-level.

The new generator room is two decks high and contains two diesel generators that are normally isolated from the ship’s service power system. However, an emergency connection is included in the distribution system. The generator room also contains equipment necessary for starting, operating, and performing maintenance on the diesel generators. Additional work is required to provide saltwater for the diesel jacket cooling systems.

A soundproof passageway is included on the 01-level on the starboard side of the generator room. This passageway has a ladder to the main deck level in order to provide an interior path to reach the radar deckhouse. Placing the generator room in this location blocked some existing mooring gear, so the mooring station at this location was moved forward. Also, mooring lines will now pass under the new passageways connecting the RSPS generator room and radar deckhouse and radar deckhouse to forecastle. Future analysis is required to determine if structural modifications are necessary to support the diesel generators.

Lastly, UNREP stations are placed on the main deck, outboard of the diesel generator room and forward of the superstructure, which coincides with the location of the shore connection manifold. The helicopter-landing pad can be used for VERTREP if necessary.

The existing superstructure was designed to accommodate a ship's complement for a T-AO mission. However, the manning required for CJ2 is significantly smaller than for a T-AO. In its original configuration, the ship has 146 staterooms and separate dining, recreation, and laundry facilities for officers, chief petty officers, and the ship's crew. For the CJ2's total crew of seventy, numerous staterooms and facilities are available for conversion to other uses.

The routing of the radar system's diesel generator exhaust uptakes is the only impact of this conversion on the superstructure. The three independent diesel generators were placed on the main deck just forward of the superstructure. In order to create space for the exhaust, a total of twelve staterooms were removed, four on the port side of the superstructure and eight higher in the deckhouse. From the diesel compartment, the exhaust lines run aft into the 01-level and through the superstructure. Halfway through the superstructure, the exhaust lines turn vertical until they emerge in a new secondary casing on the 06-level. This route was chosen to minimize conversion work and because the existing casing did not have room for the new uptakes. Additional research is required to ensure that the exhaust ducting does not exceed the back-pressure limit of the diesel generators.

The CJ2 tank layout is identical to the T-AO 187 tank layout. However, dramatic changes were made to the tank loading due to the removal of cargo fuel. A discussion of tank loading is included in the structural analysis. The CJ2 tank layout is provided in Appendix E.

As previously discussed, this platform provides more than enough space in the deckhouse for CJ2 personnel support. The detailed arrangement areas and footprints for CJ2 equipment were unavailable at the time of this writing. However, MIT/LL provided area estimates based on previous research. These estimated area requirements are summarized in Table 13.[10]

Table 13. Estimated CJ2 Area Requirements

Component	Area Required (ft^2)
X-Band Transmitter	200
S-Band Transmitter	300
S-X Signal Processing Equipment	300
S-X Operating Consoles	300
Data Processing Equipment	200
Telemetry Equipment	300
Communications Equipment	200
Spares and Storage	500
Range Control Center	200
Total Required	**2500**
Total Available	**8615**

The radar deckhouse on the main deck provides ample area for the interior mission equipment. The space allocated to telemetry equipment in the forecastle has 400 square feet available, and the mission control rooms alone contain 3600 square feet each. Therefore, the ship has excess area and space available for the CJ2 mission.

4.1.7 Structural Design and Intact Stability

Prior to performing a structural analysis of CJ2, adjustments were made to the lightship weight distribution in order to reflect the changes made during conversion. The ASSET model of the T-AO 187 was used to track the items removed and added during the conversion process. The weights added or removed, along with their vertical and longitudinal centers of gravity, were tracked according by SWBS group. A detailed accounting of items removed and added is included in Appendices A and B, respectively. Table 14 summarizes the results of the one-digit weight group changes.

Table 14. Summary of Weight Changes

SWBS Group		Weight Change (ltons)	LCG Change (ft)	VCG Change (ft)
100	Hull Structure	-472.4	-4.57	-0.03
200	Propulsion Plant	-15.2	0.06	0.09
300	Electric Plant	354.9	-13.22	5.00
400	Command and Surveillance	181.3	-51.24	4.96
500	Auxiliary Systems	-353.6	-6.37	-5.40
600	Outfit and Furnishings	10.2	-1.20	1.21
700	Armament	-19.1	191.30	-10.65
Total		**-313.9**	**-3.39**	**0.04**

The data for the removed and added items was converted into weight blocks for modification of the lightship weight distribution in the T-AO 187 model in the Program of Ships Salvage and Engineering (POSSE). The weight block modifications were used to adjust the lightship weight distribution in POSSE to match the converted ship displacement and centers of gravity calculated using ASSET. The original and conversion hull lightship weight distributions are shown in Figures 11 and 12, respectively.

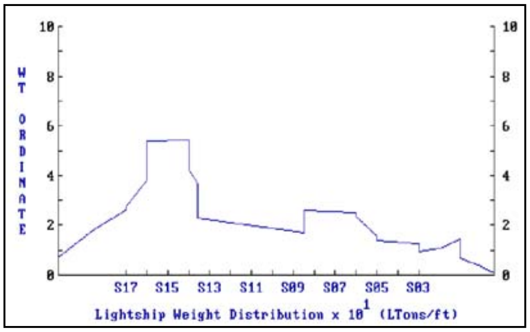

Figure 11. T-AO 187 Lightship Weight Distribution

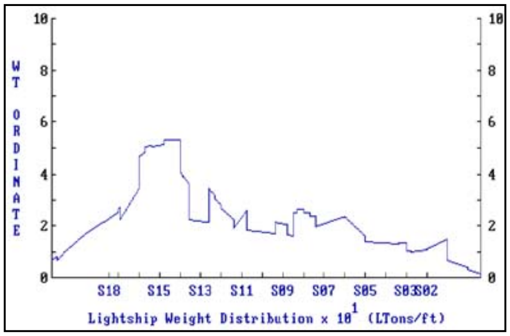

Figure 12. CJ2 Lightship Weight Distribution

Two tank loading conditions were analyzed during the structural and stability analyses. The full load (FL) condition used the same tank loading scheme for the fuel oil, lube oil, fresh water and stores as used in the original full load T-AO 187 model. All cargo fuel oil and cargo JP-5 tanks were emptied and then re-filled as described below for the appropriate ballast condition and all other cargo was removed. The minimum operating (MIN OP) condition reduces the amount of fuel oil, lube oil, fresh water, and stores to one-third of their full load values. The layout of these tanks is identical to the MIN OP loading condition for the original T-AO 187. The fixed ballast in the converted cargo fuel oil and cargo JP-5 tanks remained the same in both the FL and MIN OP conditions. Variable seawater ballast from the original seawater ballast system was used in both loading conditions for final compensation of trim and heel. A detailed description of the tank loading for both conditions is included in Appendix E.

The three materials considered for use as fixed ballast were water, Perma-Ballast™, and lead. Water was used as the basis for determining which tanks to fill since it is the only liquid of the three options. In order to mitigate free-surface effects, all fixed water ballast tanks were filled completely until the ship was in a reasonable trim; only full tanks were used. Finally, variable seawater ballast was then used to adjust trim and heel.

Based on the intact stability analysis discussed below, water was found to be the only suitable ballast material due to the reduced roll period associated with the two denser ballast materials. Although there may be other adequate, if not better, loading conditions, research into optimizing tank loading is beyond the scope of this report. Using water ballast in the tank layouts described above provides reasonable assurance that the conversion design meets all stability, strength, and seakeeping requirements.

The section properties used to determine the structural adequacy of the conversion design were taken from the T-AO 187 POSSE model. Data for five ship sections was provided, and values at other locations were determined by interpolation or by extending the midship section data for sections of the parallel-midbody. Sectional diagrams are included in Appendix F for comparison between the cross-sectional diagrams from ASSET and POSSE.

The allowable bending stress at each section was determined using the requirements from DDS-100 for hull girder primary strength. The design primary stress (f_{ID}) is given by

$$f_{ID} \geq f_{IC} + M_s$$

where f_{IC} is the calculated primary stress, and M_s is the stress factor for primary strength. The value of the stress factor for primary strength required for a non-combatant ship is 0.5 tons per square inch (TSI). The design primary stress must be less than the design primary stress limit (F_1), which for high strength steel (HSS) is 9.5 TSI. Therefore, the limit for calculated primary stress is 9 TSI. Using the calculated design primary stress and the section modus data provided, the allowable bending moment (M) at each section was calculated using

$$\sigma = \frac{M}{Z}$$

where Z is the section modulus and σ is the allowable stress (calculated primary stress).

The conversion design was evaluated for intact structural strength adequacy in still water and in waves. In the case of waves, both the hogging and sagging conditions were evaluated using a trochoidal wave, with the wave height (h) given by:

$$h = 1.1\sqrt{LBP}$$

The converted ship performed satisfactorily in all conditions for both the full load and minimum operating conditions. The detailed structural analysis is included in Appendix F. Table 15 summarizes the results of the structural analysis.

Table 15. Intact Structural Analysis Summary

Wave Condition	Loading Condition	Max Shear Stress (ksi)	Max Bending Stress (ksi)	Bending Stress (%)
Stillwater	FL	2.45	5.76	32%
	MIN OP	3.70	6.92	38%
Hogging	FL	5.69	16.08	89%
	MIN OP	5.62	16.03	89%
Sagging	FL	3.12	14.87	82%
	MIN OP	3.20	14.26	78%

An intact stability analysis was performed for the T-AGM 23, T-AO 187, and CJ2 in order to compare the three hulls. Three cases were analyzed and compared: still water, hogging, and sagging (waves with wind for both hogging and sagging). Additionally, 100-knot beam winds and a high-speed turn were evaluated for the still water condition.

The still water analysis was performed for loading conditions using the water ballast and Perma-Ballast™ (315 lb/ft^3 and 210 lb/ft^3). The results for KG and GMT are summarized in Table 16.

Table 16. Intact Stability Comparison Summary

Hull and Loading Condition	Displacement (ltons)	KG (ft)	GMT Corrected (ft)
T-AGM 23 FL	23,404	22.86	7.41
T-AO 187 FL	40,963	32.24	7.69
CJ2 FL (fresh water)	35,161	32.56	8.72
CJ2 MIN OP (fresh water)	33,450	32.78	8.05
CJ-2FL (Perma Ballast™ 315)	35,159	22.47	14.35
CJ2 MIN OP (Perma Ballast™ 315)	33,448	22.47	14.15
CJ2 FL (Perma Ballast™ 210)	35,159	23.79	14.46

Based on these preliminary findings, the roll period was estimated as described in the seakeeping section of this report. After calculating the roll periods of the variants using different ballast materials, it was determined that only water provided an adequate roll period. The lead ballast conditions were assumed to be worse than the Perma Ballast™ conditions and were not analyzed. Therefore, the stability analyses were limited to water ballast cases only.

Table 17 summarizes the results for the intact stability analysis in still water. Comparing the CJ2 conversion design with the Observation Island shows that CJ2 possesses a larger righting arm (GZ) while exhibiting comparable heel angles in both beam winds and high speed turns. The result of the intact stability analyses for hogging and sagging seas and wind are presented in Tables 18 and 19, respectively. The results are similar to the still water case and are satisfactory for all conditions.

Table 17. Still Water Intact Stability Summary

Hull	Max GZ (ft)	Angle of Max GZ (deg)	Heel Angle (deg)	Heel Angle Beam Wind (deg)	Heel Angle HST (deg)
T-AGM 23 FL	4.14	47.2	1.2P	3.2	3.2
T-AO 187 FL	4.11	35.5	1.05P	4.8	4.0
CJ2 FL	5.88	39.0	0.0	4.0	3.0
CJ2 MIN OP	5.65	38.7	0.0	4.5	3.4

Table 18. Hogging Intact Stability Summary

Hull	Max GZ (ft)	Angle of Max GZ (deg)	Wind Heel Angle (deg)	Range of Positive GZ (deg)
T-AGM 23 FL	2.83	60.1	7.9	>58.5
T-AO 187 FL	2.78	60.1	5.6	>58.8
CJ2 FL	4.16	48.9	4.4	>60.0
CJ2 MIN OP	3.82	45.3	5.1	>60.0

Table 19. Sagging Intact Stability Summary

Hull	Max GZ (ft)	Angle of Max GZ (deg)	Wind Heel Angle (deg)	Range of Positive GZ (deg)
T-AGM 23 FL	5.41	41.9	5.2	>59.0
T-AO 187 FL	6.34	40.4	3.6	>59.2
CJ2 FL	7.63	42.4	2.9	>60.0
CJ2 MIN OP	7.20	41.9	3.1	>60.0

The water-ballasted conversion design is adequate for all intact stability conditions required. Further details of these analyses are included in Appendix G.

4.1.8 Damaged Stability and Structural Analysis

A floodable length curve was created using the ASSET model output. In accordance DDS-079, the floodable length of a non-combatant over 300 ft is 12.5% of the LBP. Applying this criterion to the CJ2, the floodable length was determined to be 81.25 ft. The resulting floodable length curve for CJ2 is shown in Figure 13.

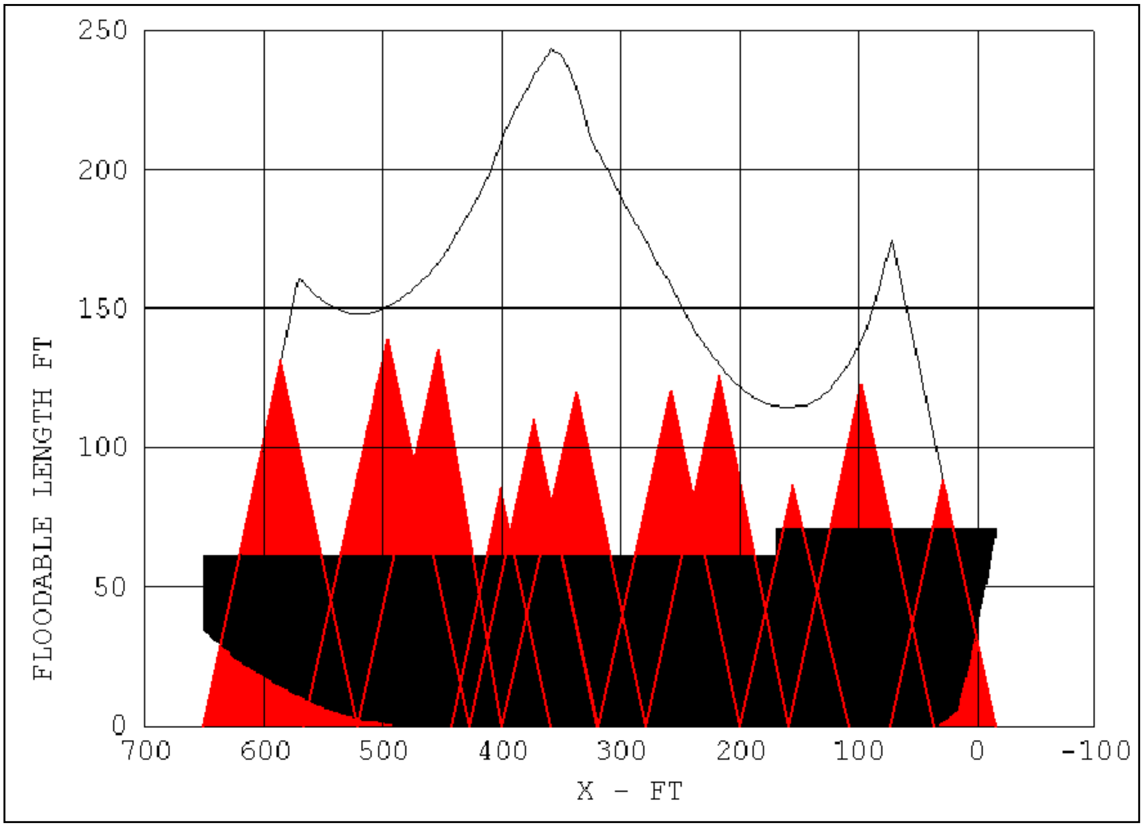

Figure 13. CJ2 Floodable Length Curve

Based on the floodable length curve, damaged cases with 50-knot winds were analyzed for both loading conditions in still water. The complete results of the damaged structural and stability analyses are included Appendices F and G, respectively.

The results of the damaged stability analysis are presented in Appendix G. The conversion design meets all stability requirements of DDS-079 for damaged stability. Damage cases are sequenced from aft (case 12) to forward (case 1) using the compartments flooded determined by the floodable length curve.

The results of the damaged stability and structural analyses are summarized graphically in Figures 14 and 15, respectively, for the full load and minimum operating load conditions. The conversion design performs satisfactorily in both loading conditions.

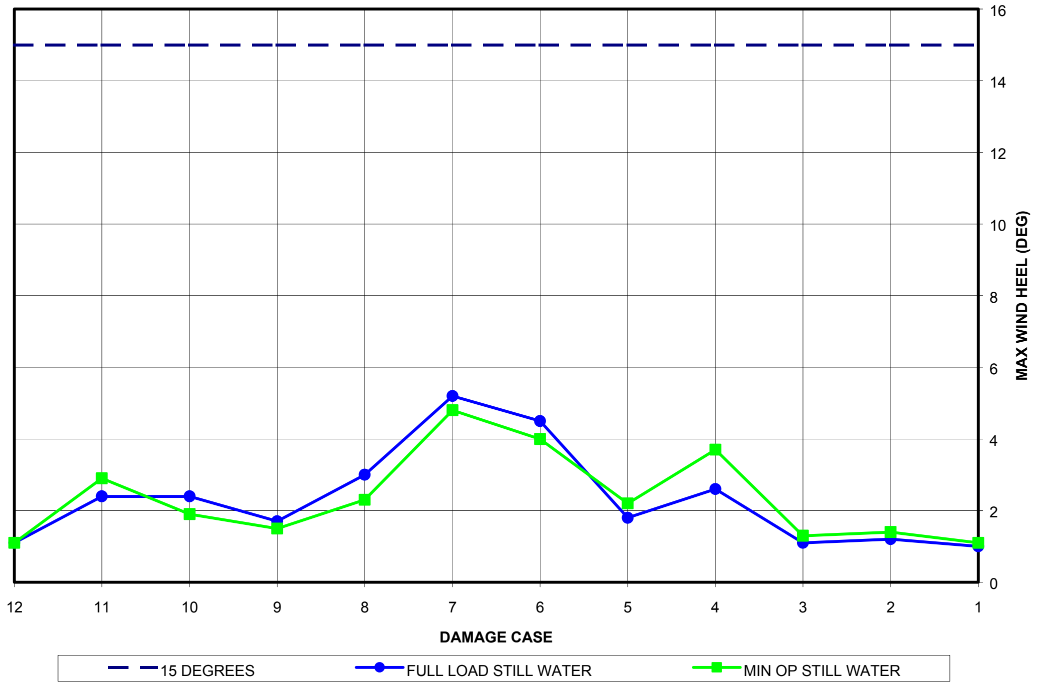

Figure 14. Damaged Stability Analysis Summary

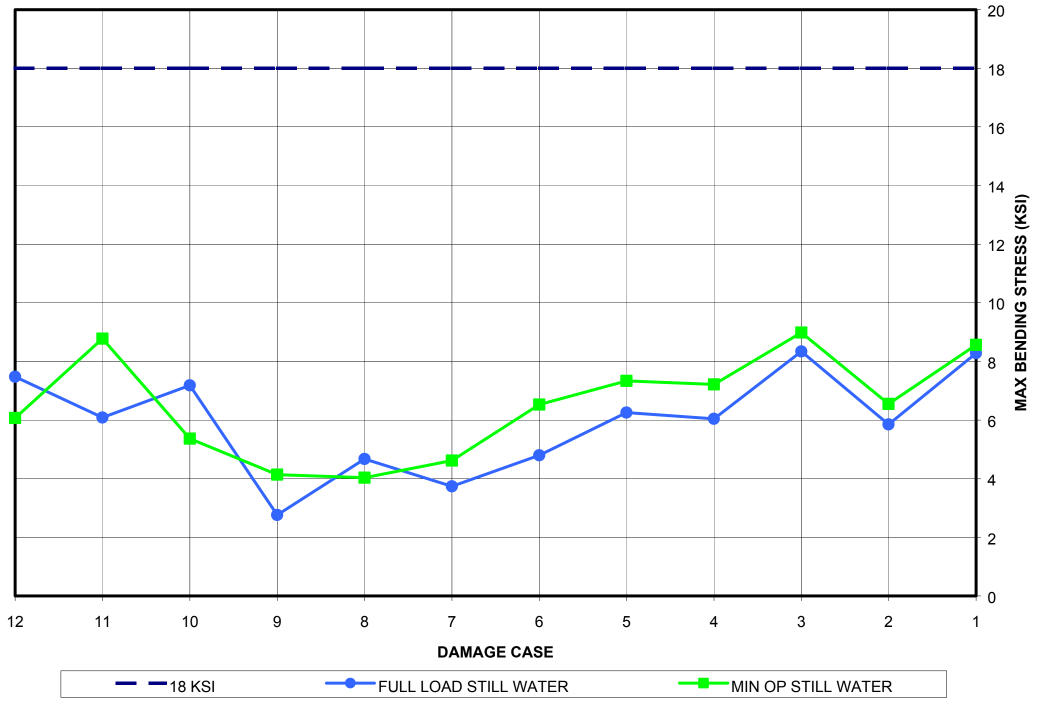

Figure 15. Damaged Structural Analysis Summary

4.2 Performance Analysis

4.2.1 Mission

The primary mission of the CJ2 is to act as a Mobile Test Range Asset in order to monitor domestic ballistic missile testing. The flexibility of a mobile platform enables a single asset to monitor tests at multiple sites, when planned accordingly. The capability of the ship to remain at sea for up to 60 days ensures that it can be available for extended periods of time in a variety of locations.

The secondary mission of the CJ2 is to aid in the development and testing of new technologies supporting ballistic missile monitoring. As radars, telemetry, and communications systems evolve, testing will be required to validate performance. The CJ2's capability to act as a radar testbed ensures continuous development.

4.2.2 Survivability and Signatures

There are no survivability or signature requirements for CJ2 since it is a noncombatant.

4.2.3 Seakeeping and Maneuvering

The T-AO 187 hull currently has good seakeeping characteristics, as it is a relatively large, heavy ship (at full load) with a low KG. The only significant change to the ship during the conversion that affected seakeeping was the replacement of cargo fuel with water ballast. Since the total ballast is less than the total cargo removed, the ship's seakeeping characteristics changed slightly.

CJ2 is required to operate in conditions of Sea State 5 and below. For the purpose of this conversion, sea states in the northern Pacific Ocean were modeled using the Pierson-Moskowitz Spectrum with significant wave height 3.25 m and wave period of 9.7 sec. The Ship Wave Analysis (SWAN) software tool was used to evaluate the response of the ship in these conditions. The ship was evaluated for speeds of 9, 14, and 19 knots in head seas and beam seas. Table 20 summarizes the SWAN seakeeping results for CJ2.

Table 20. SWAN Seakeeping Results

Motion	Location	Limit (RMS)	Max Value (RMS)	Worst Case Condition
Roll	CG	4°	3.73°	19 knots/beam seas
Pitch	CG	1.5°	0.99°	14 knots/head seas
Vertical Acceleration	Bridge	0.2g	0.03g	14 knots/beam seas
Lateral Acceleration	Bridge	0.1 g	0.07g	19 knots/beam Seas

The ship meets all NATO STANAG limits for both head and beam seas. SWAN was unable to calculate ship motions at speeds less than 9 knots; however, the seakeeping characteristics for ships do not vary much at such low speeds, so the analysis is adequate. Appendix H includes a full analysis of seakeeping characteristics for CJ2, T-AO 187, and T-AGM 23 for comparison purposes.

Figure 11 shows the maximum vertical accelerations of the major CJ2 components.

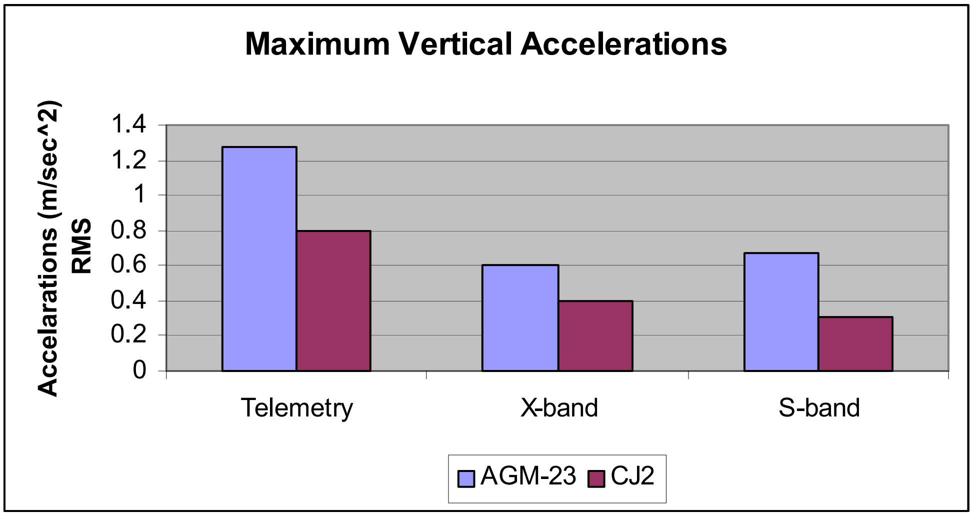

Figure 16. CJ2 Equipment Accelerations

The largest accelerations are for the telemetry equipment, as expected, because the dishes are located near the bow of the ship. Due to the high accelerations, the control stations for the telemetry gear was placed amidships with the radar control stations in order to minimize effects to telemetry operators. Further discussion of the SWAN seakeeping analysis is included in Appendix H.

The roll period of CJ2 was determined in order to ensure conversion changes did not drastically reduce the roll period of the T-AO 187. Most large ships have a roll period of approximately 10-16 seconds, and the wave period of larger storms is close to 9 seconds. Table 21 summarizes the results of the roll period calculations.

Table 21. Roll Period Comparison

Ship	Roll Period (sec)
T-AGM 23	13.3
T-AO 187	12.9
CJ2	13.2

The complete roll and pitch period calculations are included in Appendix H.

4.2.4 Environmental

As the conversion did not affect waste processing equipment, the ship maintains the same level of environmental standards and remains in compliance with US Navy policy for waste disposal. In fact, the removal of approximately 25000 ltons of cargo fuel significantly reduces the environmental impacts in any damaged condition.

4.3 Operation and Support

The CJ2 is projected to have approximately 30 ship's force crew and 40 CJ2 system technicians. The entire crew is required for all mission-related exercises.

4.4 Cost

A weight-based methodology developed by the MIT 13A program was used to estimate the conversion costs. The complete cost model is included in Appendix I. The estimate is broken down into removal costs, addition costs, shipyard profit factor, and post-shakedown costs. The acquisition costs of the CJ2 radars and telemetry systems are not addressed in this report. Table 22 lists the major cost estimates in FY02 dollars. The model assumed a 3% inflation rate, an in-service date of 2010, and a 30-year service life.

Table 22. Conversion Cost Estimates

Cost Category	**Cost (MDol)**
Removal Cost	17.2
Addition Cost	134.6
Profit	12.0
Shipyard Portion	**166.9**
Outfitting	3.3
Government Portion	**3.3 ****
	***** Not Including Radars***
Acquisition Cost	**170.2**
Post Shakedown Cost	**8.3**
Total Acquisition Cost	***178.6***

This weight-based cost analysis produced conservative results. An in-depth NAVSEA analysis and CJ2 acquisition cost estimation are required to provide a more accurate assessment.

5.0 Design Conclusions

5.1 Summary of Final Concept Design

The conversion of a Henry J. Kaiser (T-AO 187) class oiler to a Mobile Test Range Asset fulfills an immediate need for the Cobra Judy replacement. Table 23 summarizes the CJ2 conversion design.

Table 23. CJ2 Conversion Design Summary

LBP	650 ft
B	98 ft
T	31 ft
Full Load Displacement	35161 ltons
KG	32.6 ft
Max. Speed	20 knots
Range	9300 nm (at 15 kts)
Seakeeping	Operable in Sea State 5
Conversion Cost	179 MDol

5.2 Final Concept Design Assessment and Conclusions

This report demonstrates the feasibility of converting a T-AO 187 class oiler into a Mobile Range Test Asset with the Cobra Judy II instrumentation suite. Performing alterations and additions on a need-basis and retiring equipment in-place when possible minimized total costs. Modifications were limited primarily to the main deck and 01-levels. Both decks were razed, and the radars were placed on the 01-level and spaced accordingly. The original main deck, which was open on the port and starboard sides, was enclosed and converted to mission spaces. The addition of a separate diesel generating system for the radars required creation of a new compartment on the main deck just forward of the deckhouse, as well as conversion of berthing space to exhaust ducting. Table 24 summarizes the removals and additions to the original ship.

Table 24. Summary of Removals and Additions

Removals	Additions
UNREP equipment Combat Systems	S-band phased-array radar system X-band phased-array radar system Telemetry equipment Diesel Generating system

A considerable amount of cargo volume was filled using water ballast in order to maintain favorable stability characteristics. However, a large amount of excess arrangeable area (approximately 6000 square feet) exists after converting the ship, and since the crew size is dramatically reduced, there is space for 40-50 additional people. The additional deck space and berthing is available for use as required by the sponsor. The CJ2 would provide and ideal platform for development and testing of new ballistic missile testing technologies.

One major issue of concern was encountered during the course of this conversion. The first ship in the T-AO 187 class has been shown to exhibit vibrations when operated at high speeds. The CJ2 mission is based upon operating at loiter speeds of 3-5 knots, but the 15-knot transit speed could induce vibrations. Details on the severity of these vibrations were not available at the time of this writing. It must be noted that despite these vibrations, the T-AO 187 class is considered the workhorse of the fleet. The hulls that are currently in operation are essential in providing UNREP needs for deployed and training forces. If there are structural issues resulting from vibrations, the effects must not be of immediate concern. Should problems arise later, methods to mitigate effects of vibrations are available and can be put into practice. In any case, these vibrations must be measured and analyzed in order to evaluate possible effects, regardless of conversion prospects.

This report describes ship conversion concept design results based on CJ2 sensor estimates. Further analysis is required in the following areas:

- High speed vibration issue resolution
- Determination of specific CJ2 component weights, VCGs, and areas
- Detailed structural analysis of hull and radar deckhouse (finite element level)
- Development of North Pacific Ocean sea spectrum
- Cost model refinement.

Based on this preliminary study, the conversion of a T-AO 187 class oiler to a Cobra Judy II Mobile Test Range Asset is feasible and merits consideration.

Appendix B: Drawings

01_level_after
01_level_prior
02_level_aft
02_level_fwd
03_level
04_level
05_level
06_level
cj2_rendering
inboard_profile_after
inboard_profile_prior
main_deck_prior
mian_deck_after
outboard_profile_after
outboard_profile_prior

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