N94-25098

FUTURE SPACE TRANSPORTATION SYSTEM ARCHITECTURE AVIONICS REQUIREMENTS

Presented to
NASA LaRC Workshop on Guidance, Navigation, Controls, and Dynamics for Atmospheric Flight
March 18, 1993
by

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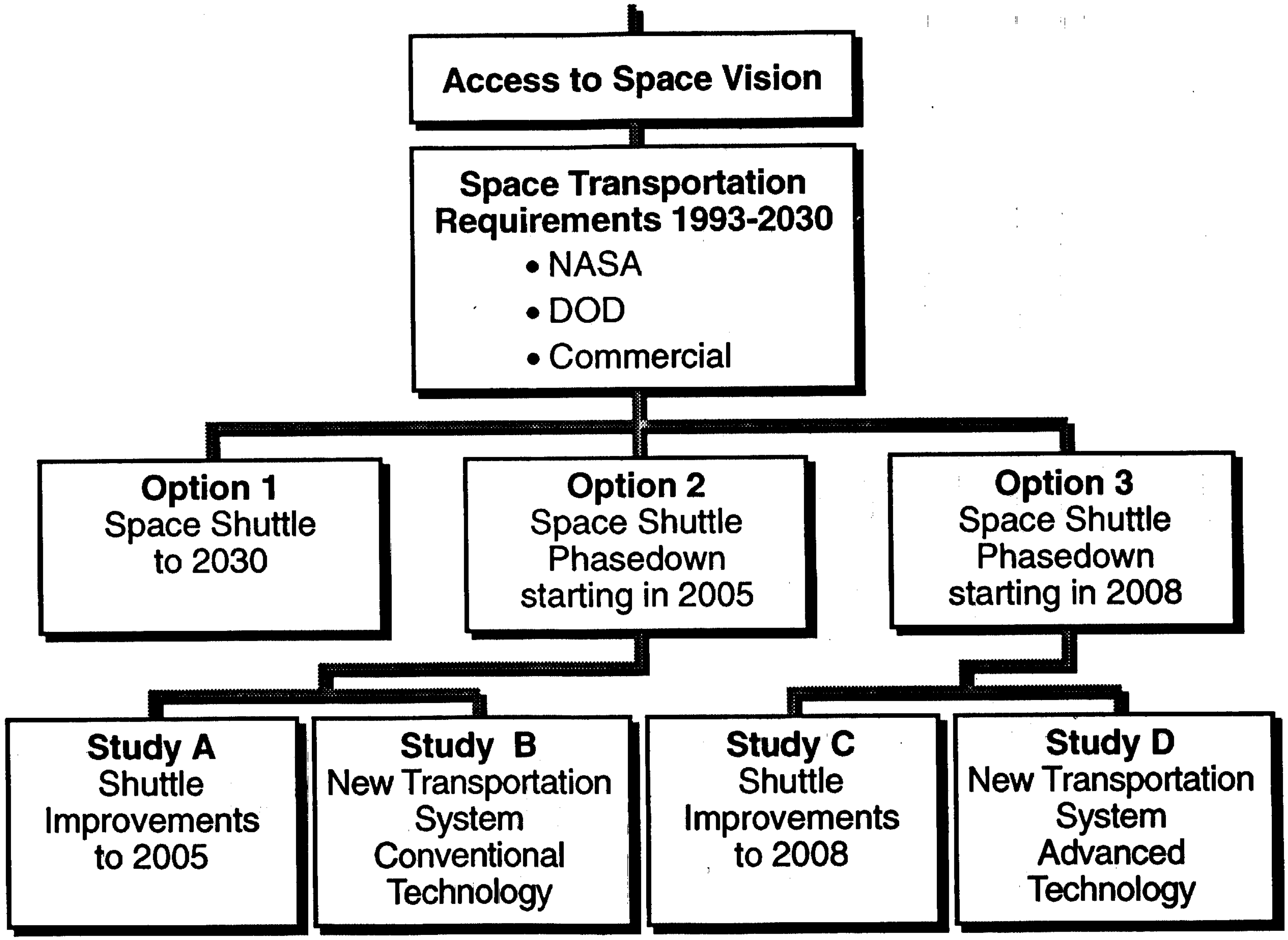
NASA STRATEGY FOR ACCESS TO SPACE



NASA Strategy for Access to Space

The agency began a multi-center study in January 1993 to examine options for providing the most cost effective space transportation system in the future. The Space Shuttle will be the primary transportation system for the near future and throughout the deployment of the Space Station Freedom later in this decade. Future options are to replace the Space Shuttle in 2005 to 2008 or improve the Space Shuttle and keep it flying to about 2030. If the Space Shuttle is replaced in 2005, more conventional technology systems would be used such as spacecraft deployed by an expendable launch vehicle. If the replacement is delayed until about 2008, it is believed that advanced technology concepts could be used such as fully reusable systems.

In the current study which is due to end this summer, many concepts will be examined, and preliminary cost numbers will be generated to see which option is the most cost effective. Technology requirements and plans will be defined to chart the path for the agency program in the next several years.

ACCESS TO SPACE EVALUATION CRITERIA

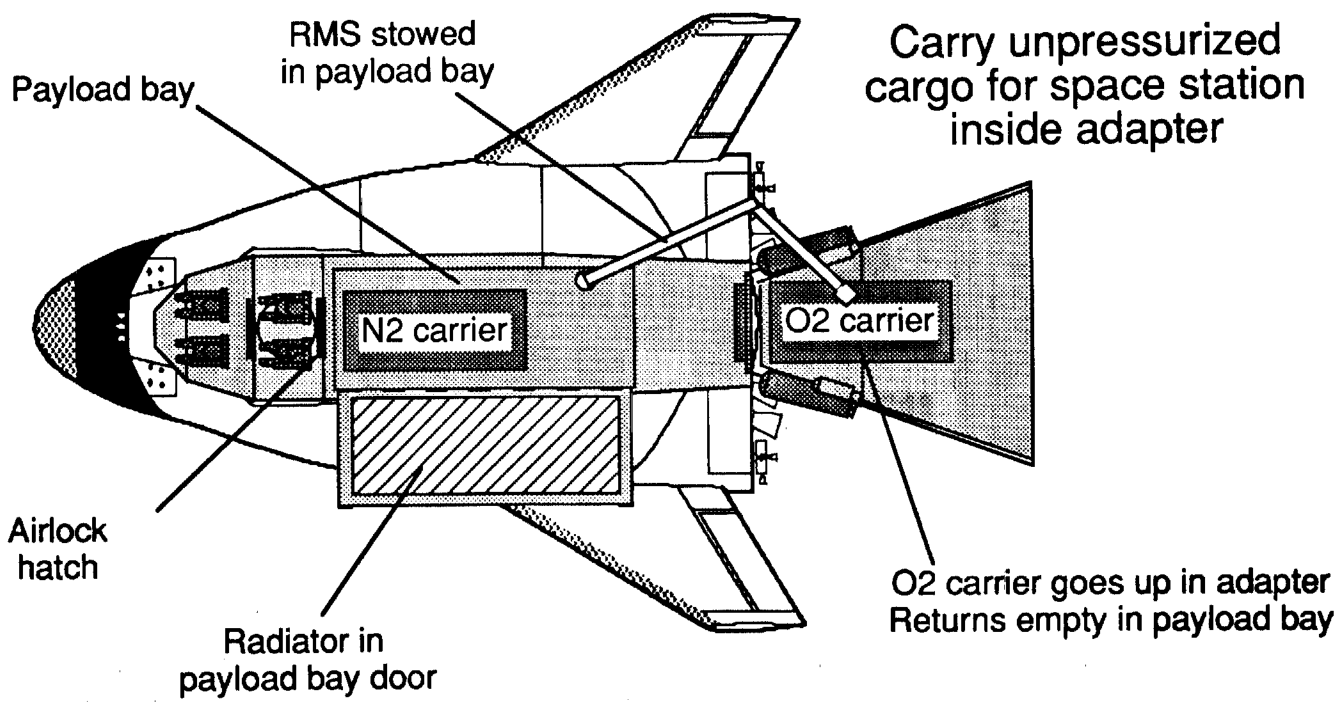
Fundamental Requirement	Key Requirement (Mandatory)	Essential Characteristics (Highly Desirable)	Desired Features (Nice to Have)
1.1 Satisfy the National Launch needs • Commercial • DOD • NASA unmanned • NASA manned Includes definition of payloads from small to exploration class, and destinations at all inclinations	2.1 Improve crew safety (crew survivability ≥ 0.999) 2.2 Acceptable life cycle cost: Affordable DDT&E and annual operations cost 50% or less over current systems 2.3 Vehicle reliability at least 0.98 2.4 Growth capabilities 2.5 Environmental – meet all requirements planned for year 2002 2.6 Good operability (flexibility, availability, responsiveness)	3.1 Acceptable program schedule 3.2 Acceptable program risks (technical, cost, schedule) 3.3 Improves commercial competitiveness of launch vehicles 3.4 Contributes to industrial economy (dual-use technology and processes) 3.5 Helps maintain industrial base	4.1 Maintain (or improve) national prestige 4.2 Promote science and education 4.3 Enable incremental development or improvements 4.4 Enhance international relationships 4.5 Improve capability relative to current systems (including STS)

Access to Space Evaluation Criteria

The fundamental requirement of the new space transportation options is to satisfy the national launch needs. In the current study, the needs are dominated by the Space Station Freedom crew rotation and resupply requirements.

Mandatory requirements include a high probability of crew survivability which drives the vehicle design to provide for abort, particularly during the critical ascent phase. The cost requirements imply that new ways of doing business must be found for future systems.

SERVICER VEHICLE OPTION FOR UNPRESSURIZED STATION CARGO



Split HL-42 adapter jettisoned at booster separation exposing unpressurized cargo -- RMS on HL-42 servicer version places cargo on station

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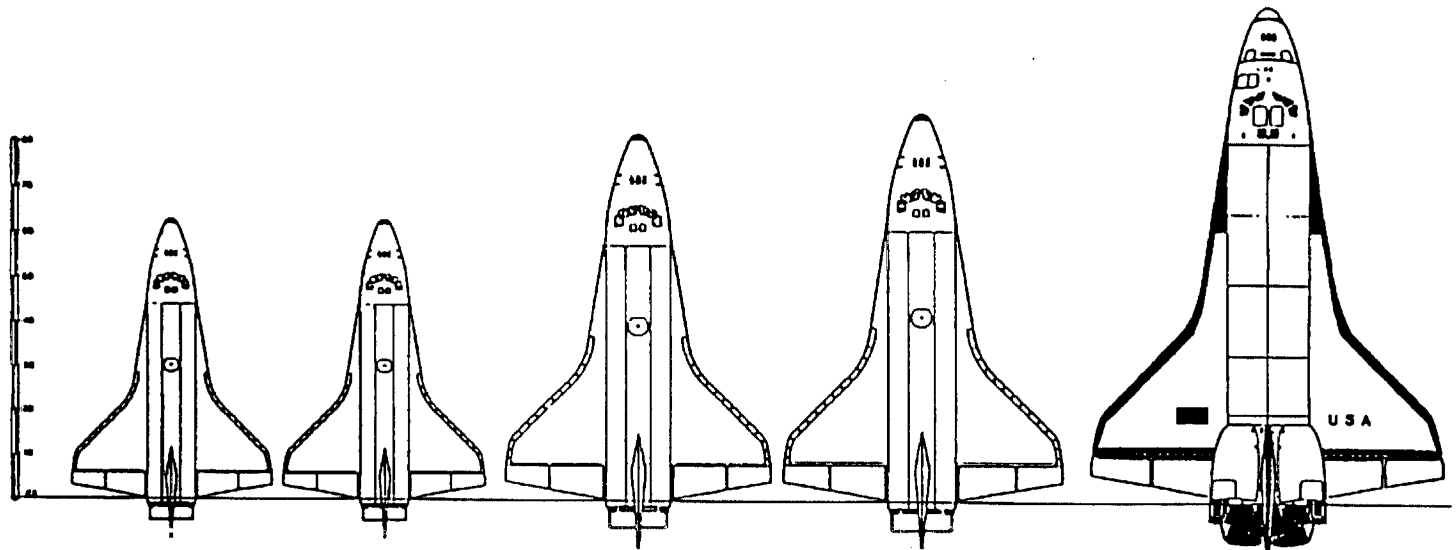
Servicer Vehicle Option for Unpressurized Station Cargo

In the conventional technology option, 2B, the Langley-developed, lifting-body concept, the HL-20 Personnel Launch System, is a candidate concept for carrying personnel and cargo requiring late access to the Space Station. Since cargo delivery requirements are being included in the current study, the HL-20 has been enlarged to a 42-ft length to allow for additional payload capability. This concept, which has been designated the HL-42, will also provide a satellite servicing capability as shown in the figure.

CLV Configuration Options

Crew Logistics Vehicle In-House Study



	CLV-B	CLV-P	CLV-UP	CLV-C	STS Orbiter
Linear Scale Factor (CLV/STS)	.50	.61	.79	.83	1.00
Payload Mass (kg)					
Pressurized	3908	7710	7710	7710	
Unpressurized	0	0	3175	5512	19,278
Gross Mass (kg)	32,495	43,200	59,700	66,550	104,350
Flts/Year	4	6	6	6	~~8~~ 5-6
Additional Flight Spt					
Pressurized	4 Titan IV/PLM/C	0	0	0	
Unpressurized	2 Titan IV/CTV	2 Titan IV/CTV	1 Titan IV/CTV	0	
Comments	No EVA or Sat Serv. No Unpressurized Return	No EVA or Sat Serv. No Unpressurized Return			

Lyndon B. Johnson Space Center

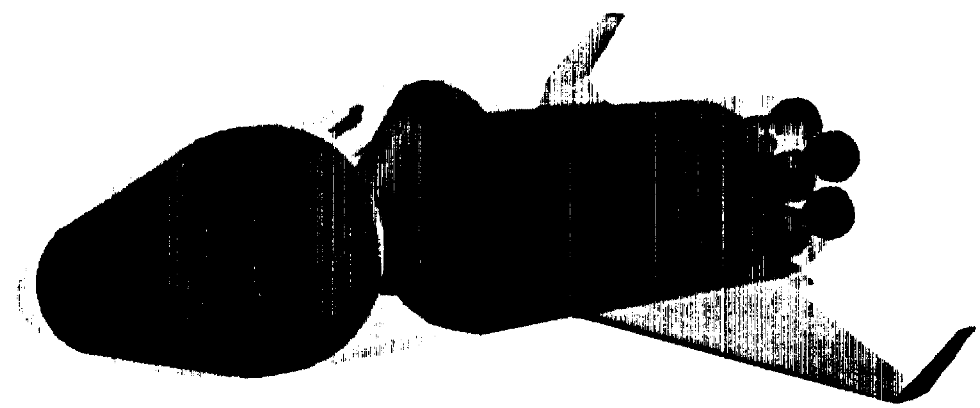
Systems Engineering Division
Systems Definition Branch

CLV Configuration Options

Also in option 2B, the Johnson Space Center team has been examining several photographically reduced Space Shuttle concepts for launch on an expendable booster. These concepts have no main propulsion systems since the booster supplies all the ascent propulsion. These concepts referred to as the Crew Logistics Vehicle (CLV), have varying cargo capability depending upon vehicle size. The largest concept, CLV-C, can carry the Space Station logistics and the station crew on a single flight, and therefore has the lowest flight rate of all the concepts. Its size and weight are also very nearly the shuttle orbiter values, and the concept would have to be side mounted on the expendable booster.

There are several other concepts being examined including a winged payload carrier, defined by the Marshall Space Flight Center, and an Apollo capsule concept which is advocated by the Johnson Space Center.

LANGLEY SINGLE STAGE ROCKET VEHICLE



GLOW	[illegible]
Dry weight	[illegible]
Length	[illegible]
Diameter	[illegible]
Span	[illegible]
IOC	[illegible]

Mission: DRM-1 Space Station Freedom resupply and crew rotation.
Deliver and return 20 klb P/L & 8 (2+6) crew to SSF from/to KSC with hard docking capability.

Langley Single Stage Rocket Vehicle

The advanced technology concepts in option 3D include rocket and airbreathing concepts. An example of an all-rocket concept is the Single Stage Vehicle (SSV) shown in the figure. This concept is fully reusable with internal cryogenic LOX and LH2 tanks and seven rocket engines in the base. Carrying all the propellant onboard results in a 171-ft long vehicle, about 50 percent larger than the Space Shuttle Orbiter. It is vertically launched and landed on a runway like the Space Shuttle.

DELTA CLIPPER PROVIDES MULTIMISSION CAPABILITY

DELTA Clipper

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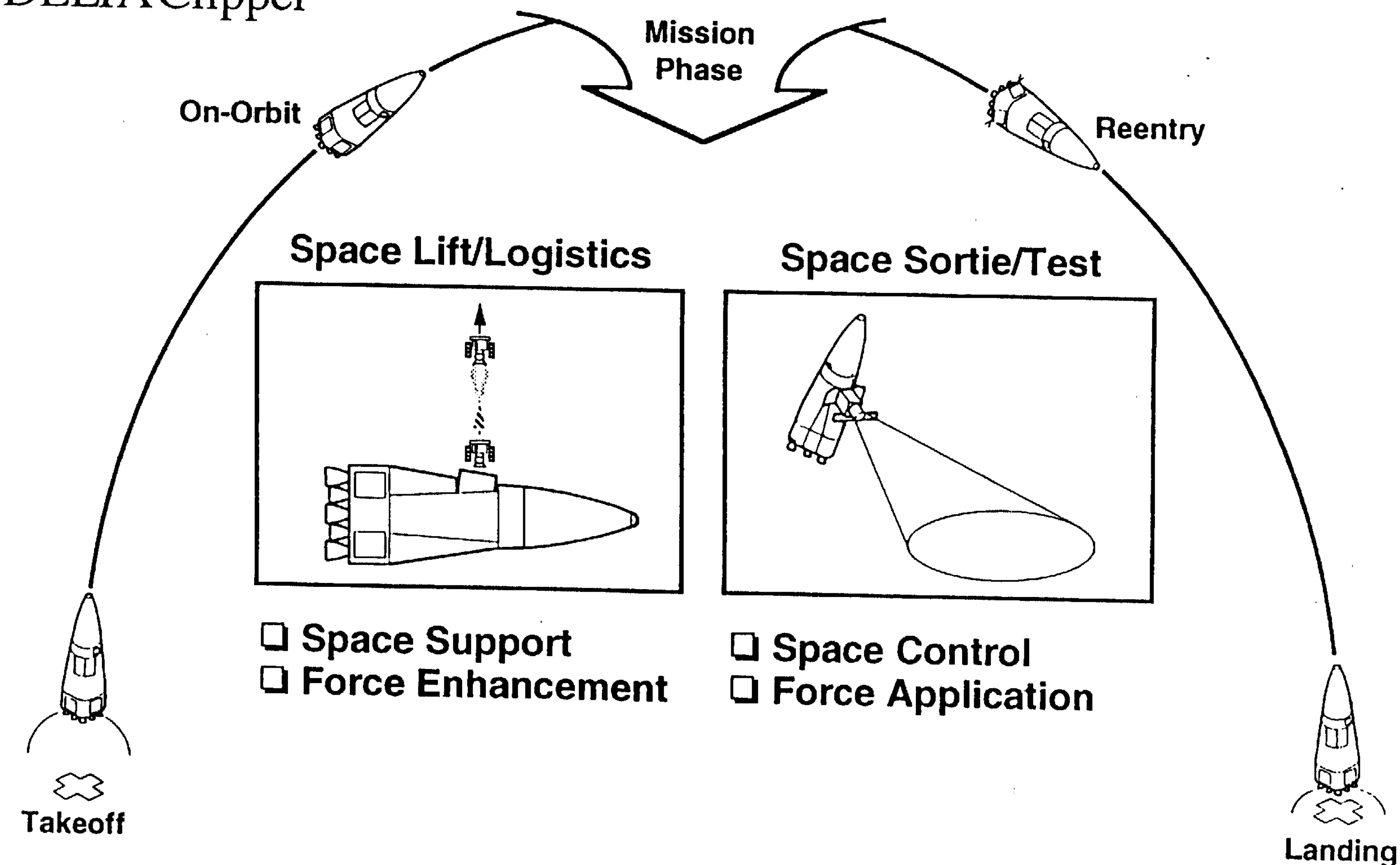
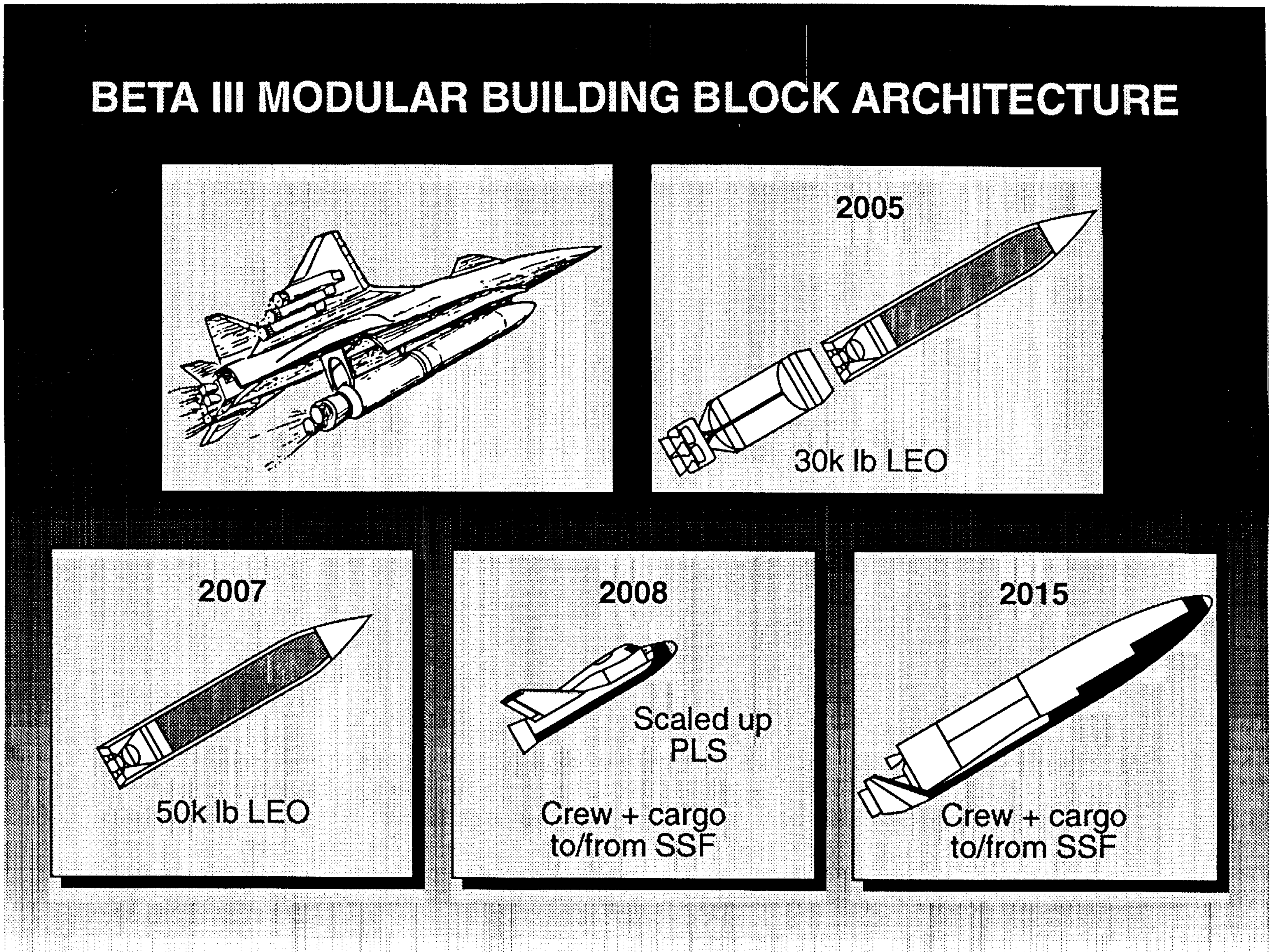


Delta Clipper Provides Multimission Capability

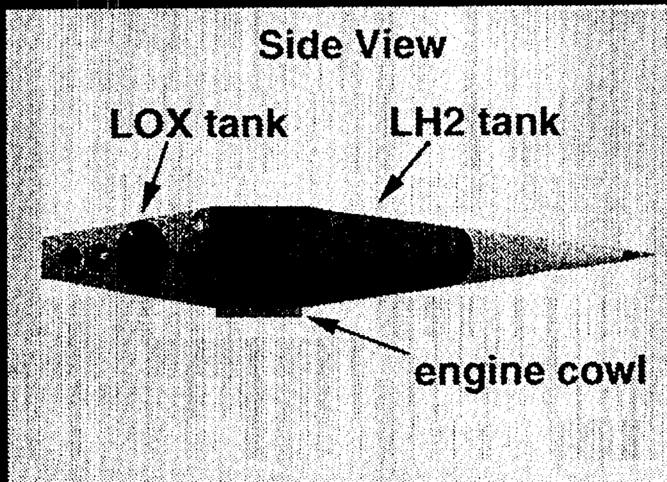
Another all rocket concept known as the Delta Clipper is being developed for the Strategic Defense Initiative Office by McDonnell-Douglas. This vehicle lifts-off vertically in a conventional manner but lands vertically using the rocket engines to achieve a soft landing. After mission completion, the vehicle enters the earth atmosphere nose first, and just before touchdown a turnaround maneuver is executed and the engines started for landing on the base. A scaled version of this vehicle has been constructed and a flight test program is due to start in a few months.

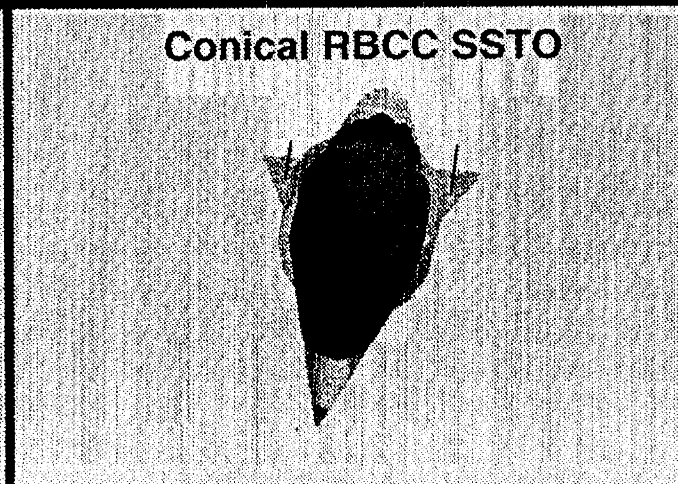

BETA III MODULAR BUILDING BLOCK ARCHITECTURE
2005
30k lb LEO
2007
50k lb LEO
2008
Scaled up PLS
Crew + cargo to/from SSF
2015
Crew + cargo to/from SSF
Stone 78

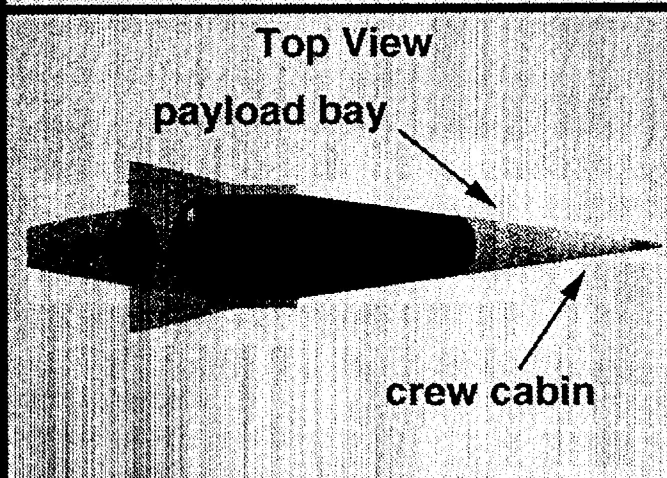
Beta III Modular Building Block Architecture

A two-stage airbreather/rocket has been studied by the Boeing Company for the NASA Lewis Research Center and the Air Force Wright Field Laboratory. This concept uses six large jet turbofan engines to lift off the runway. At a suitable altitude and speed, rocket engines on the booster and the second stage are ignited. At Mach 3 to 4 and approximately 100,000-ft of altitude, the second stage separates and goes into orbit while the booster rocket engines shut down, and the booster returns to the launch site. Several different combinations of spacecraft and upper stages could be used with this booster system.

REFERENCE RBCC SSTO DESIGN







GLOW	721,520 lbs
dry weight	136,400
mass ratio	3.918
LH2 prop wt./total prop	.356
payload bay volume	5300 ft^3
payload to 51.6° 220 Nm	25 klbs
vehicle length	288.1 ft
max. body diameter	31.0 ft
wingspan	63.2 ft

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Reference RBCC SSTO Design

A Single-Stage-to-Orbit (SSTO) airbreather/rocket concept known as the Rocket Based Combined Cycle (RBCC) vehicle has also been defined. This concept could be horizontally or vertically launched. The vehicle shown here is designed to be vertically launched. In this design, the rocket engines located within the cowl supply the initial thrust. As the speed increases, air is ducted into the cowl, and at Mach 3 the airbreathing engine system takes over. At Mach 15, the rocket engines are re-ignited for orbital insertion. This system is designed to complete the ascent trajectory quickly and not for airbreathing cruise. At the completion of the mission, this vehicle lands horizontally.

There is also a National Aerospace Plane concept being examined in this study. Thus, the potential space transportation concepts range from being rather simple and near-term technology to the more complex, far-term technology, large systems.

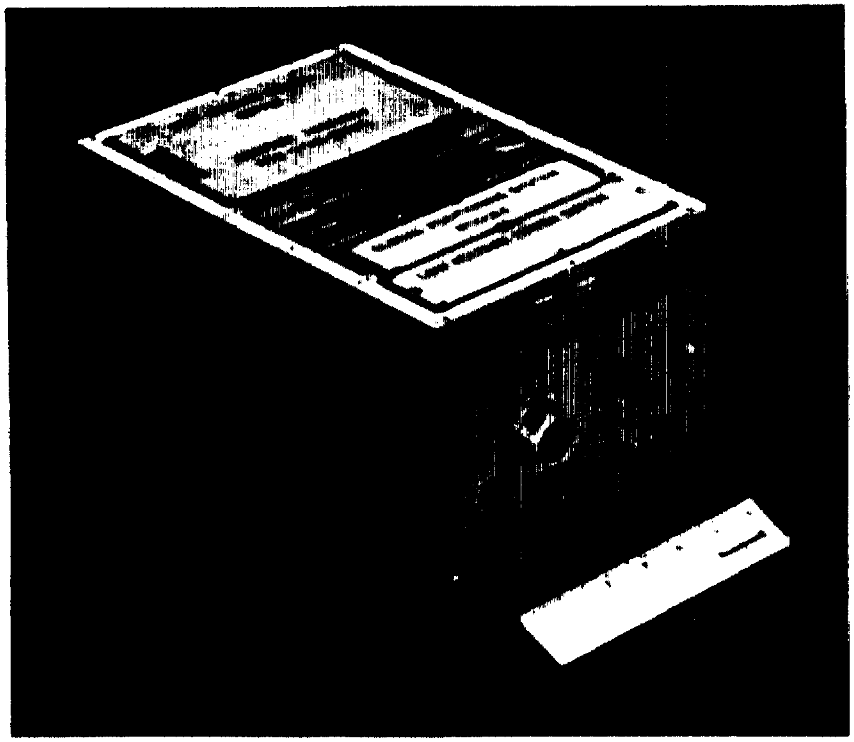
SPACE TRANSPORTATION SYSTEM VEHICLE AVIONICS REQUIREMENTS

- All weather operation
- Autonomous operations/on-board checkout
- Health monitoring
- Multifunction display and controls system
- Autoland, autorendezvous/docking
- Reliable multiple communications channels

Space Transportation System Vehicle Avionics Requirements

The key advanced avionics requirements for these vehicle concepts are envisioned to provide significantly improved operational efficiency and effectiveness. It is very desirable to have adaptive guidance, navigation, and control approaches that will allow launch and return in almost any weather condition. The vehicles must be able to accommodate atmospheric density variations and winds without software changes. The flight operations must become much more autonomous in all flight regimes like an aircraft, and preflight checkout should make use of the onboard systems. When the vehicle returns to the launch site, subsystem health must be known and maintenance tasks scheduled accordingly. Ground testing of most subsystems must be eliminated. Also, the health monitoring system must be designed to enhance the ability to abort the mission significantly and save the crew and the vehicle. The displays and controls must be much less complex than current systems and must significantly reduce pilot work load. It is important to have low power, light weight displays and controls. Rendezvous and docking and all flight phases must have autopilot capability to reduce pilot work load for routine operations and in abort situations The vehicles must have the demonstrated ability to return to the launch site. Abort from all mission phases can put additional demands on the communications system.

INERTIAL NAVIGATION SYSTEM WITH INTEGRATED GPS



Honeywell Small Lightweight GPS/INS

- Improved location capability
- Flight control outputs
- Very low life cycle costs
- No scheduled maintenance
- No re–calibration
- Extensive BIT
- No flight line test equipment

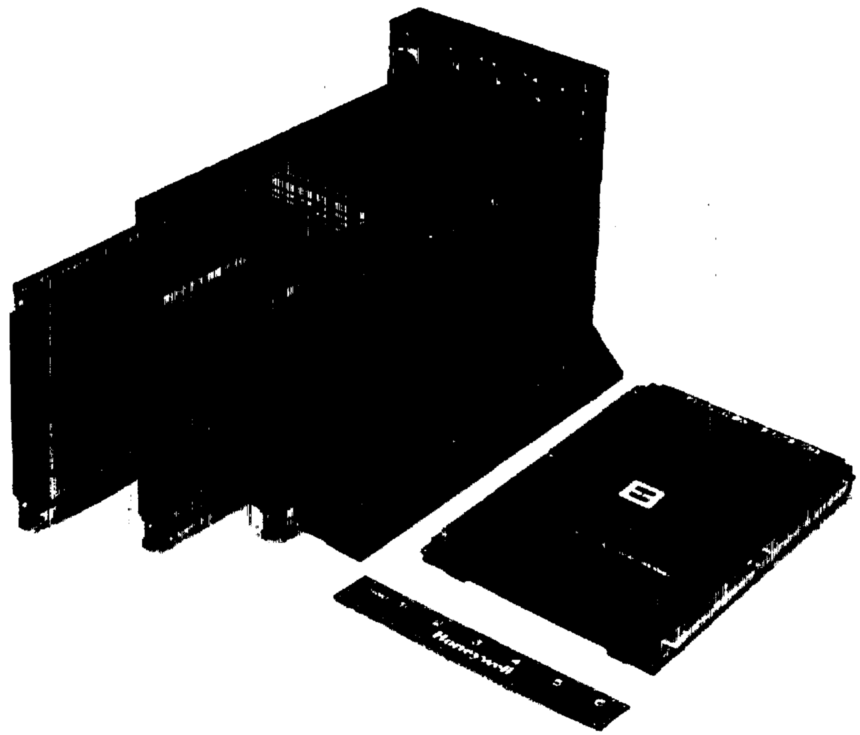
Inertial Navigation System with Integrated GPS

In order to package, weigh, and cost advanced vehicle concepts, individual subsystem components must be defined. Generally, new technology systems with some demonstrated capability are assumed except where an advanced technology will be mission enabling. In the avionics arena, the new technology components are being developed in several ongoing programs. Honeywell has developed a ring laser inertial system with a tightly coupled Global Positioning System (GPS) receiver integrated in a small, lightweight package. This package requires 65 watts power and has several operationally attractive features which are listed on the figure.

Honeywell

ASCM

Advanced Spaceborne Computer Module



Features

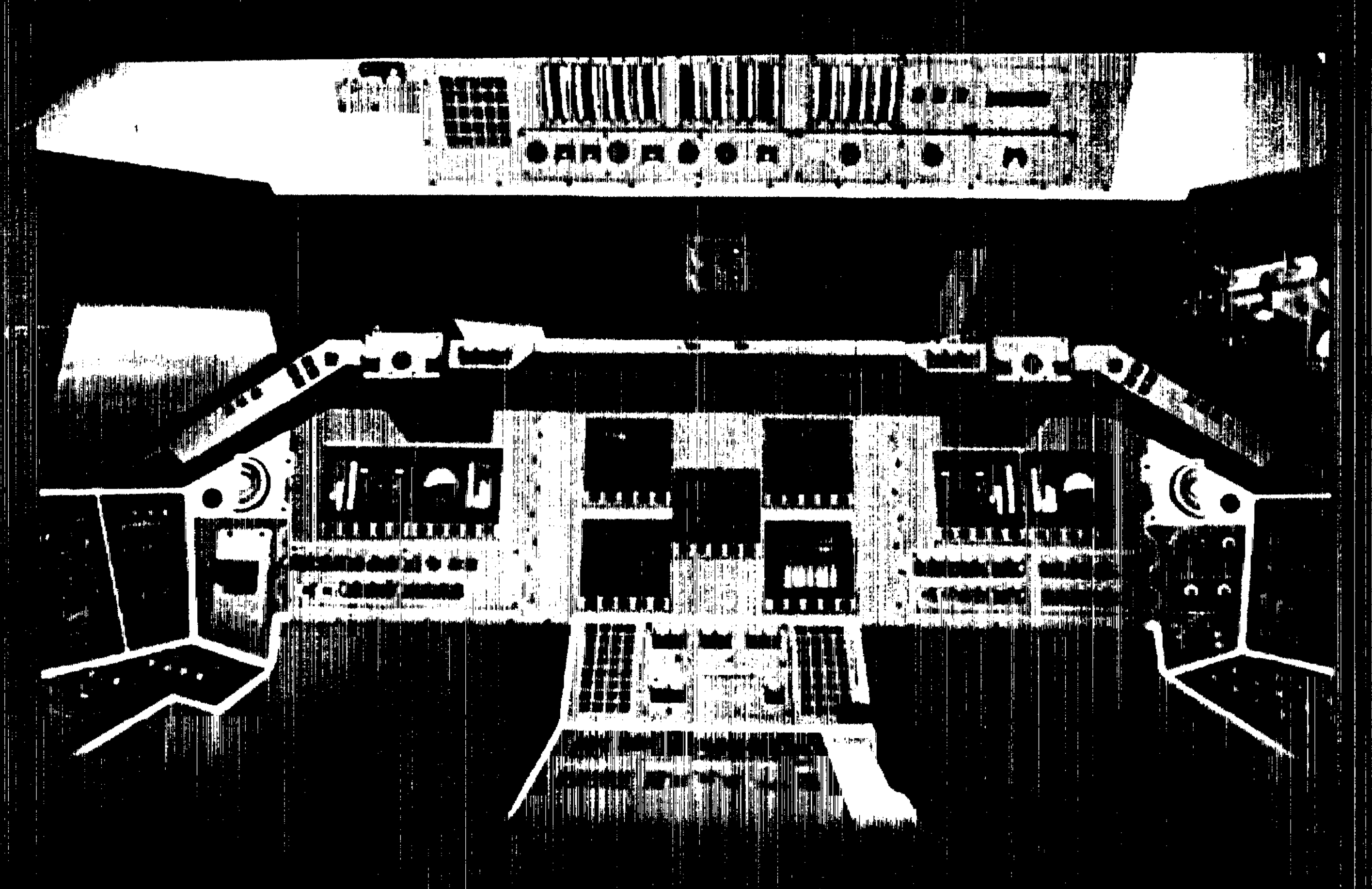
CPM-Control Processor Module

- MIL-STD 1750A processor
- 1 MBYTES main memory (8Kx8)
- 3-5 MIPS operation
- 10 MBIT/sec serial data bus
- MIL-STD 1553B serial data bus

ASCM
Advanced Spaceborne Computer Module

A Department of Defense program is funding the development of this computer package. It is a MIL-STD-1750A processor that is small, light weight, and low power with good performance and radiation hardening. At the present time, software is being developed for a self-checking pair architecture. To achieve the fail operational/fail operational/fail safe redundancy requirement generally required for manned space transportation systems, a triplex or quad system will be required. There is also an Advanced Technology Insertion Module for the processor that provides optical data bus ports.

HEADS UP DISPLAY / GLASS COCKPIT CONTROL PANEL

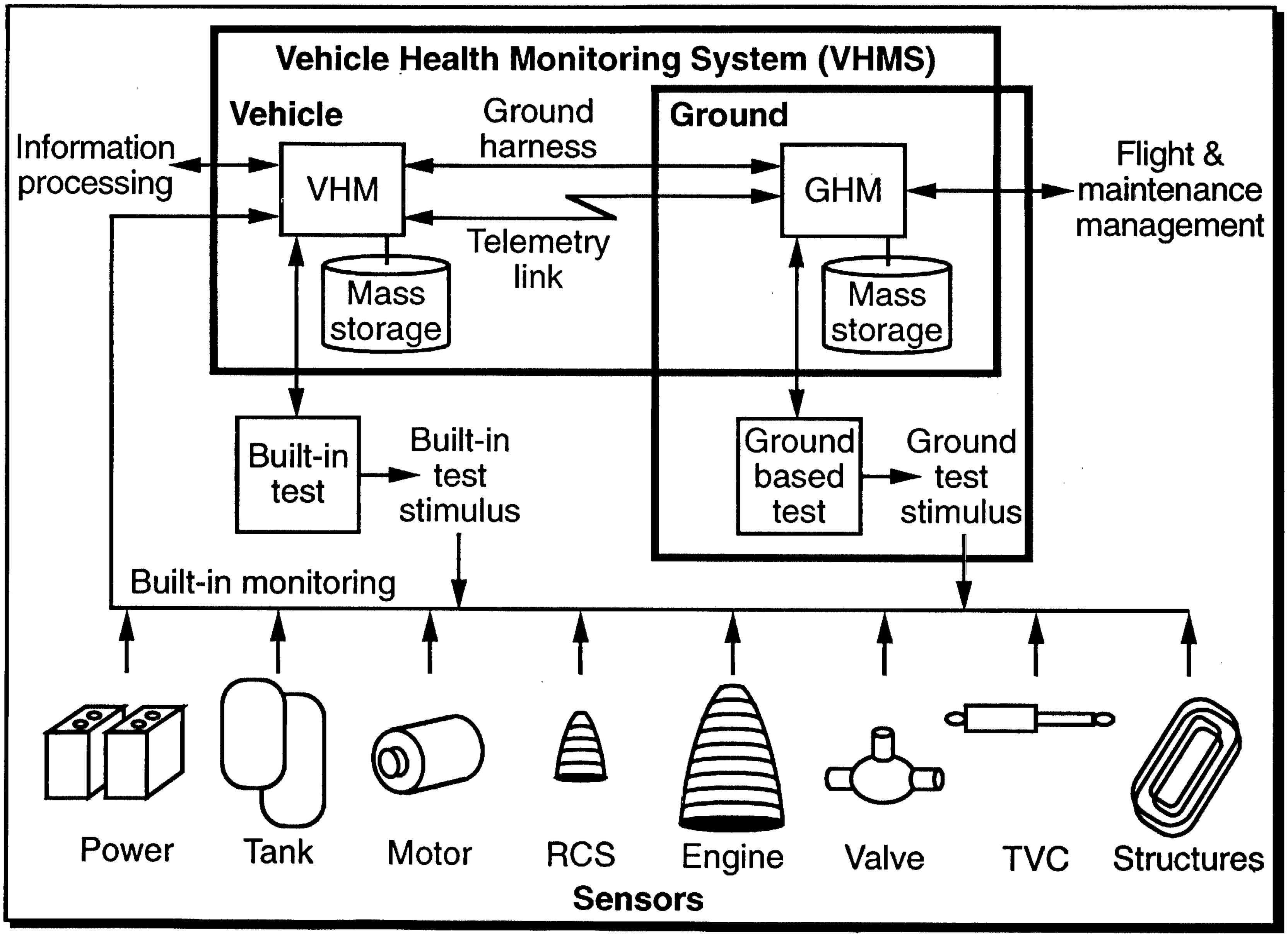


Honeywell Multifunction Electronic Display (MED) to replace [illegible] shuttle and training simulator electromechanical cockpit displays

Heads Up Display/Glass Cockpit Control Panel

A new Space Shuttle Orbiter display and control panel shown in the figure is being developed by the Honeywell Satellite Systems Operation as a subcontractor to Rockwell International. The panel has flat panel liquid crystal displays (LCD) that are programmed for several functions depending upon flight regime. These LCD panels are 6.7-in square, weigh about 16 lbs, and require about 90 watts.

VHMS ELEMENTS



VHMS Elements

The baseline Vehicle Health Monitoring System (VHMS) elements shown in the figure are based on a Boeing design for the Air Force/NASA Advanced Launch System (ALS) program that was developed 3 years ago. The ALS vehicle had a recoverable propulsion/avionics module that was to be reused. The total system has an onboard element and a ground element. The onboard element records data during the flight from the subsystems and sends notification of any potential critical failure to the vehicle information processing system. The ground element analyzes the recorded flight data for use in the ground maintenance procedures and the prelaunch checkout.

AVIONICS TECHNOLOGY FOR FUTURE SPACE TRANSPORTATION SYSTEM VEHICLES

- Demonstrate integrated health monitoring system (including reusable cryogenic tanks)
- Develop and test fault tolerant architecture (hardware and software)
- Develop and demonstrate integrated GNC system for all weather/flight condition operations

Avionics Technology for Future Space Transportation System Vehicles

In studying advanced space transportation concepts and defining the required avionics system attributes, it appears that the current advanced systems have or will soon have sufficient capability to meet the needs. The next step in technology development is to define representative systems, assemble the hardware, develop the software, and test /demonstrate the systems. An integrated health monitoring system design must be demonstrated including a viable approach for monitoring the health status of reusable cryogenic tanks flight after flight. The fault tolerant processing system development area has issues such as software testing and certification methods and dissimilar backup system requirements that must be addressed. An integrated guidance, navigation, and control system for nearly all weather operations and a viable abort capability also need further definition and demonstration.