709

N91-17022

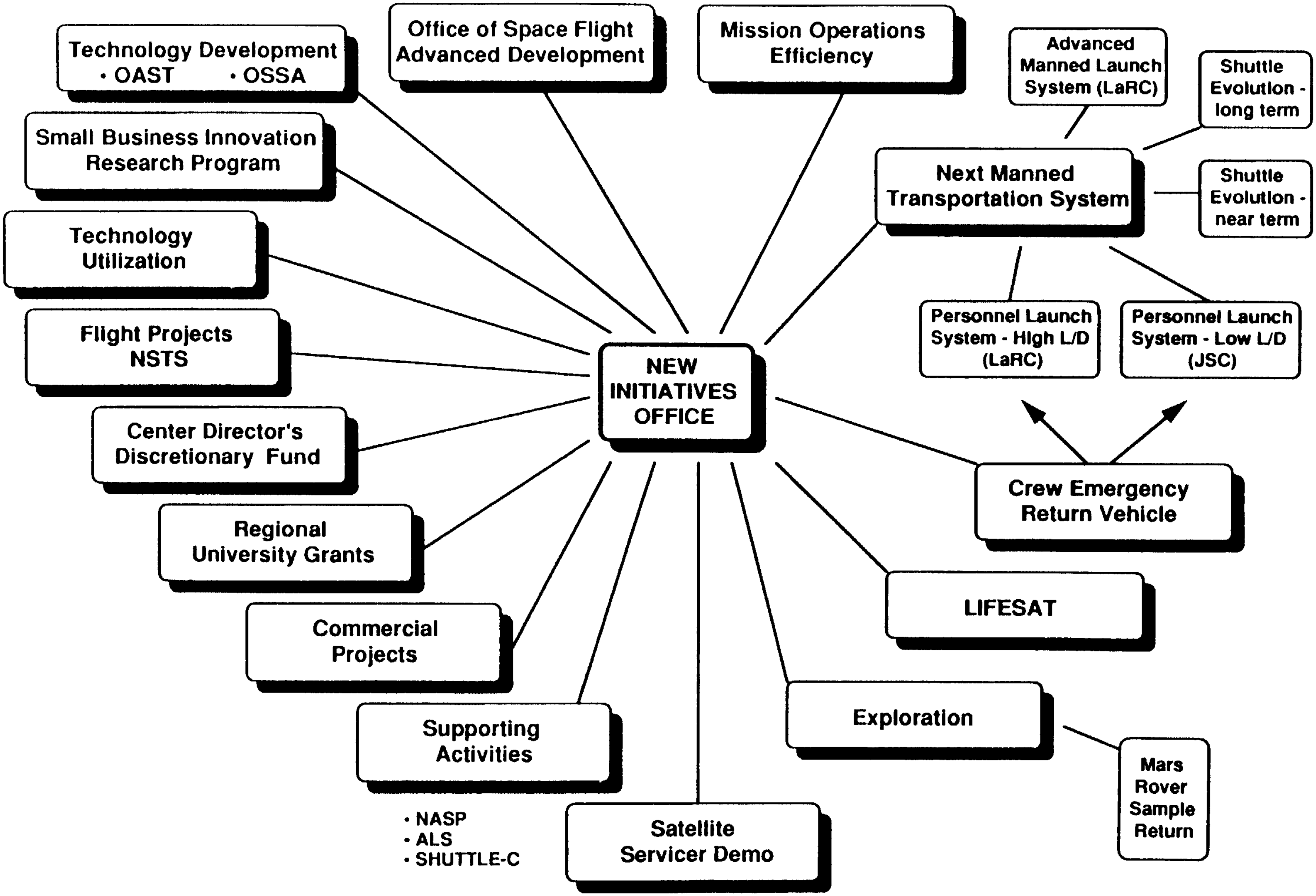
NEXT MANNED TRANSPORTATION SYSTEM

SPACE TRANSPORTATION AVIONICS TECHNOLOGY SYMPOSIUM

NEXT MANNED TRANSPORTATION SYSTEM

Harry Erwin
New Initiatives Office
Johnson Space Center

JSC's NEW INITIATIVES



NEXT MANNED TRANSPORTATION SYSTEM

What are Avionics?

Avionics are the connecting link that integrate the hardware and software which satisfy system requirements.

- Systems analysis and engineering required
- Requires detailed knowledge and definition of non-avionics subsystems
- Allows verification of flight readiness

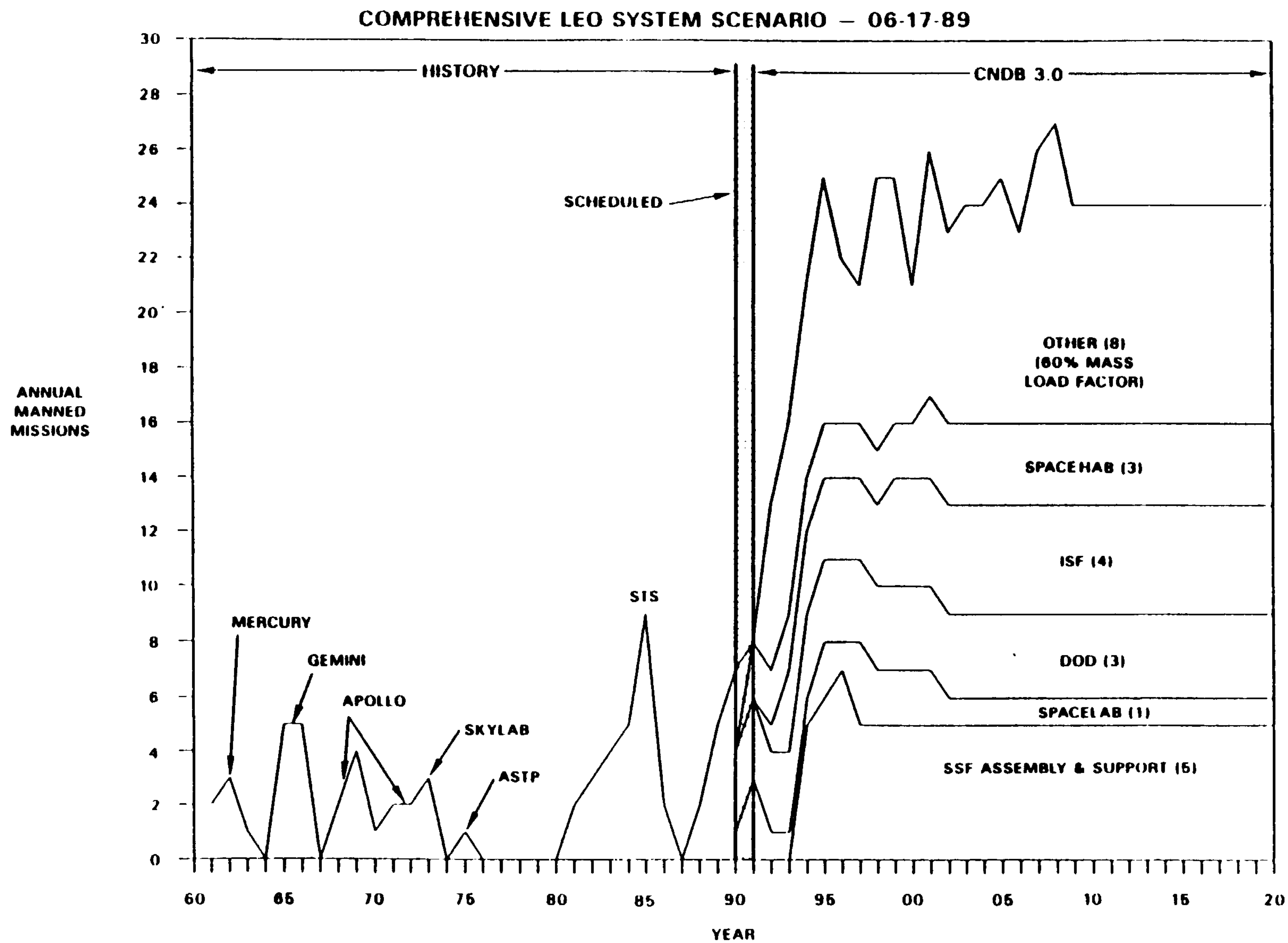
Avionics are both a part of each flight system and a process for integration.

NEXT MANNED TRANSPORTATION SYSTEM

Top-Level Considerations

- Assured manned access to space
- First-stage abort
- Lower cost of ownership

NEXT MANNED TRANSPORTATION SYSTEM



NEXT MANNED TRANSPORTATION SYSTEM

Issues

- Systems which transport people only
- Launch escape
- Down cargo
  - Blunt body reentry
  - Tethers (for trash)
  - Continuing shuttle-like capability
- Solid vs. liquid propulsion
- Systems integration of NASA programs
  - Manage programs - not projects

NASA

NEXT MANNED TRANSPORTATION SYSTEM

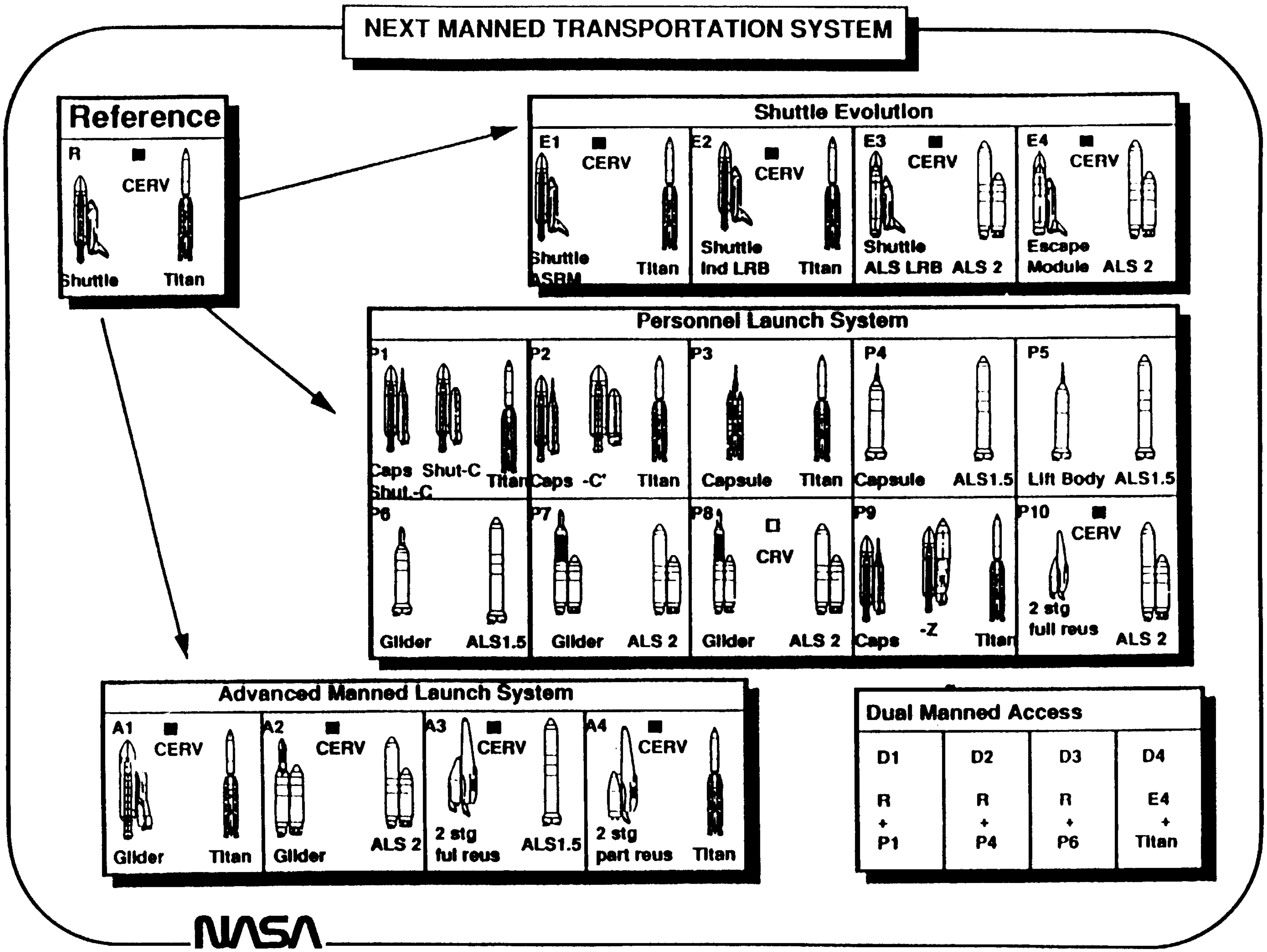
Goals

- Satisfy people/payload requirements
- Improve cost effectiveness
- Increase reliability
- Increase margins

Paths Studied to Meet Goals

- STS evolution
- Personnel launch system
- Advanced manned launch system

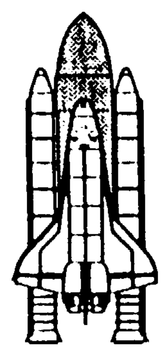
NASA


NEXT MANNED TRANSPORTATION SYSTEM
Reference
R
CERV
Shuttle
Titan
Shuttle Evolution
E1
CERV
Shuttle ASRM
Titan
E2
CERV
Shuttle Ind LRB
Titan
E3
CERV
Shuttle ALS LRB
ALS 2
E4
CERV
Escape Module
ALS 2
Personnel Launch System
P1
Caps Shut-C
Shut-C
Titan
P2
Caps -C'
Titan
P3
Capsule
Titan
P4
Capsule
ALS1.5
P5
Lift Body
ALS1.5
P6
Glider
ALS1.5
P7
Glider
ALS 2
P8
CRV
Glider
ALS 2
P9
Caps
-Z
Titan
P10
CERV
2 stg full reus
ALS 2
Advanced Manned Launch System
A1
CERV
Glider
Titan
A2
CERV
Glider
ALS 2
A3
CERV
2 stg ful reus
ALS1.5
A4
CERV
2 stg part reus
Titan
Dual Manned Access
D1
R + P1
D2
R + P4
D3
R + P6
D4
E4 + Titan

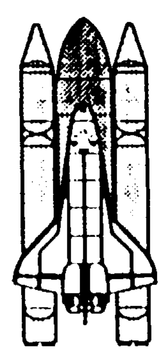
NEXT MANNED TRANSPORTATION SYSTEM

NMTS Candidate Concepts

Shuttle Evolution

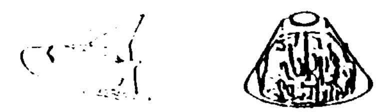


Current STS

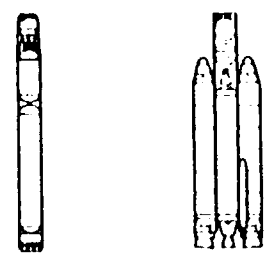


Evolved STS

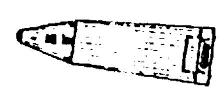
Personnel Launch System (PLS)



Crew Modules

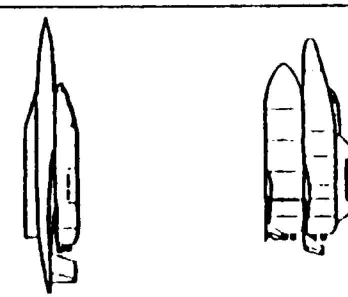


Launch Vehicles

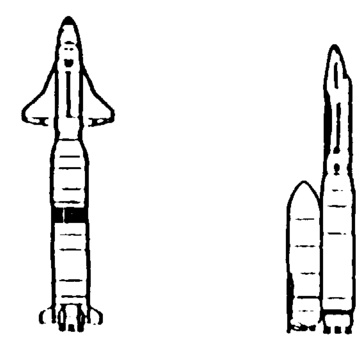


Cargo Return Vehicle

Advanced Manned Launch System (AMLS)



Fully Reusable

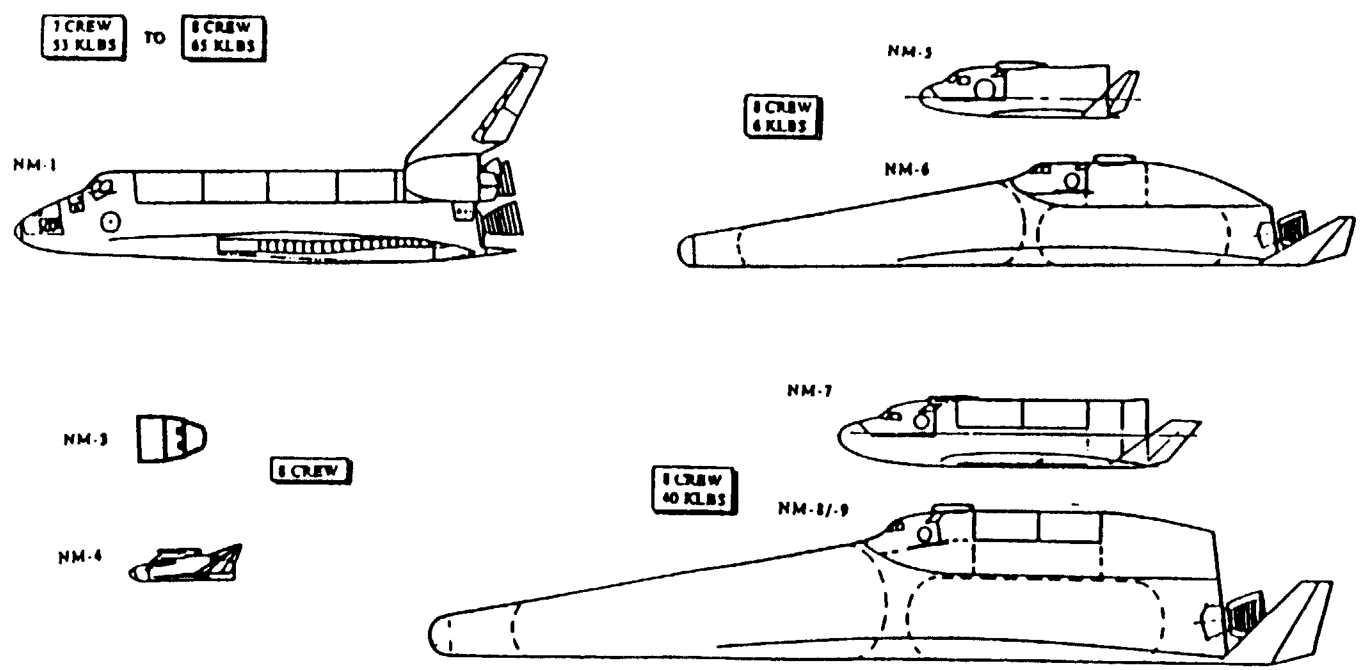


Partially Reusable

NEXT MANNED TRANSPORTATION SYSTEM

Next Manned Options

NM-1	Current Orbiter	NM-6	Fully Reusable 2 Stage (PLV)
NM-2	Improved Orbiter (crew escape capsule)	NM-7	Large Glider (AMLS)
NM-3	Ballistic (low L/D Capsule - PLV)	NM-8	Fully Reusable 2 Stage (AMLS)
NM-4	Lifting Body (PLV)	NM-9	Partly Reusable 2 Stage (AMLS)
NM-5	Glider (PLV)	NM-10	Ballistic (Low L/D) CERV



NEXT MANNED TRANSPORTATION SYSTEM

STS Evolution

- Exploit new technologies
- Build on existing engineering data base
- Minimize mold-line/configuration changes
- Counter obsolescence
- Increase people carrying capability

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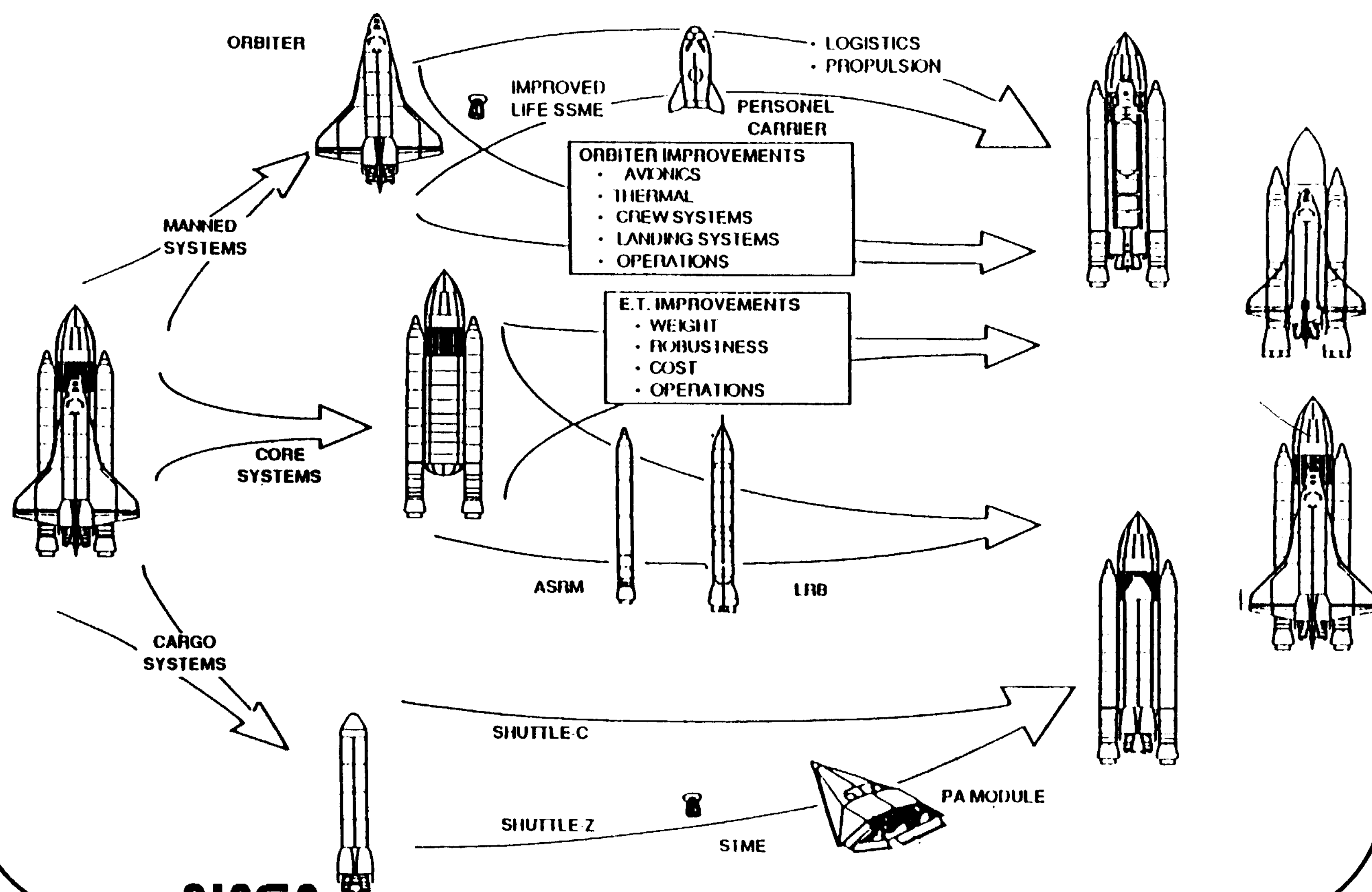
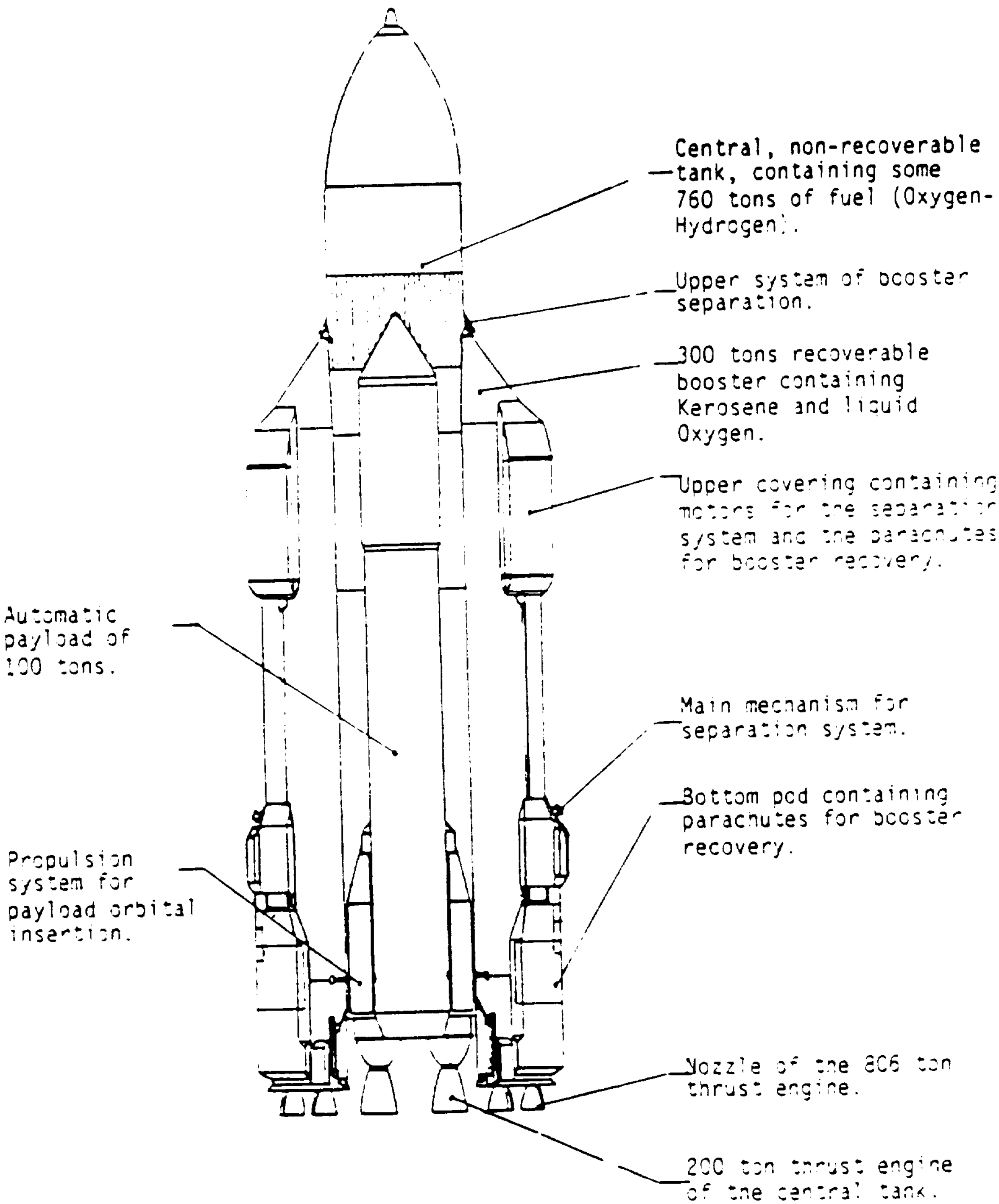
NEXT MANNED TRANSPORTATION SYSTEM

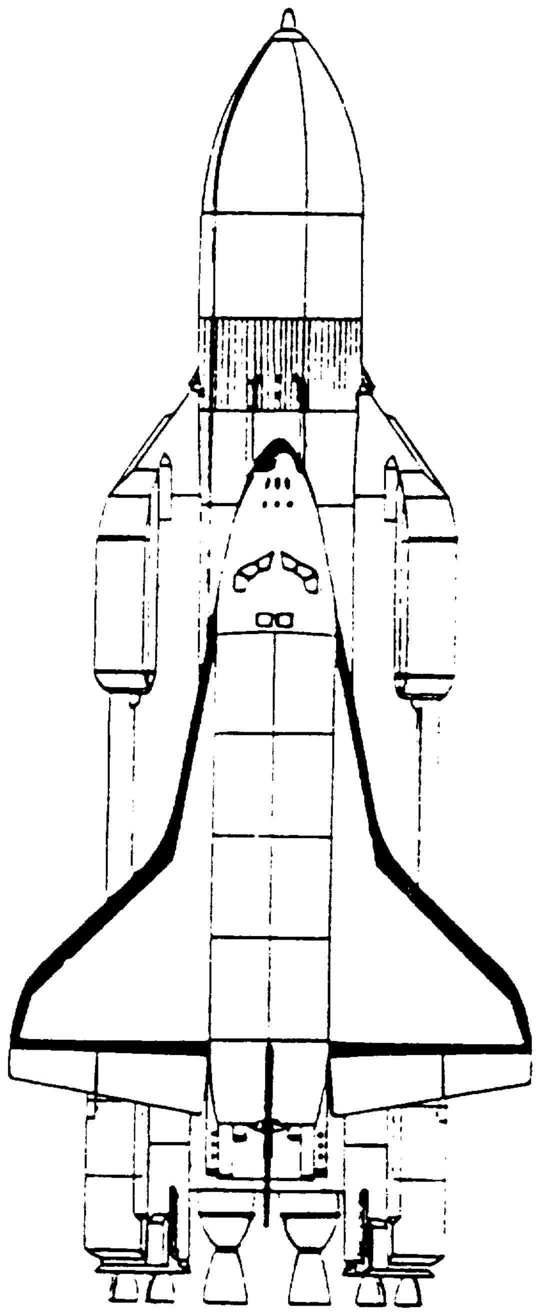
Shuttle Evolutionary Path



Configuration of the super-heavy Energiya booster, with automatic payload



Super-heavy Booster "Energiya" In Configuration With The Space Shuttle



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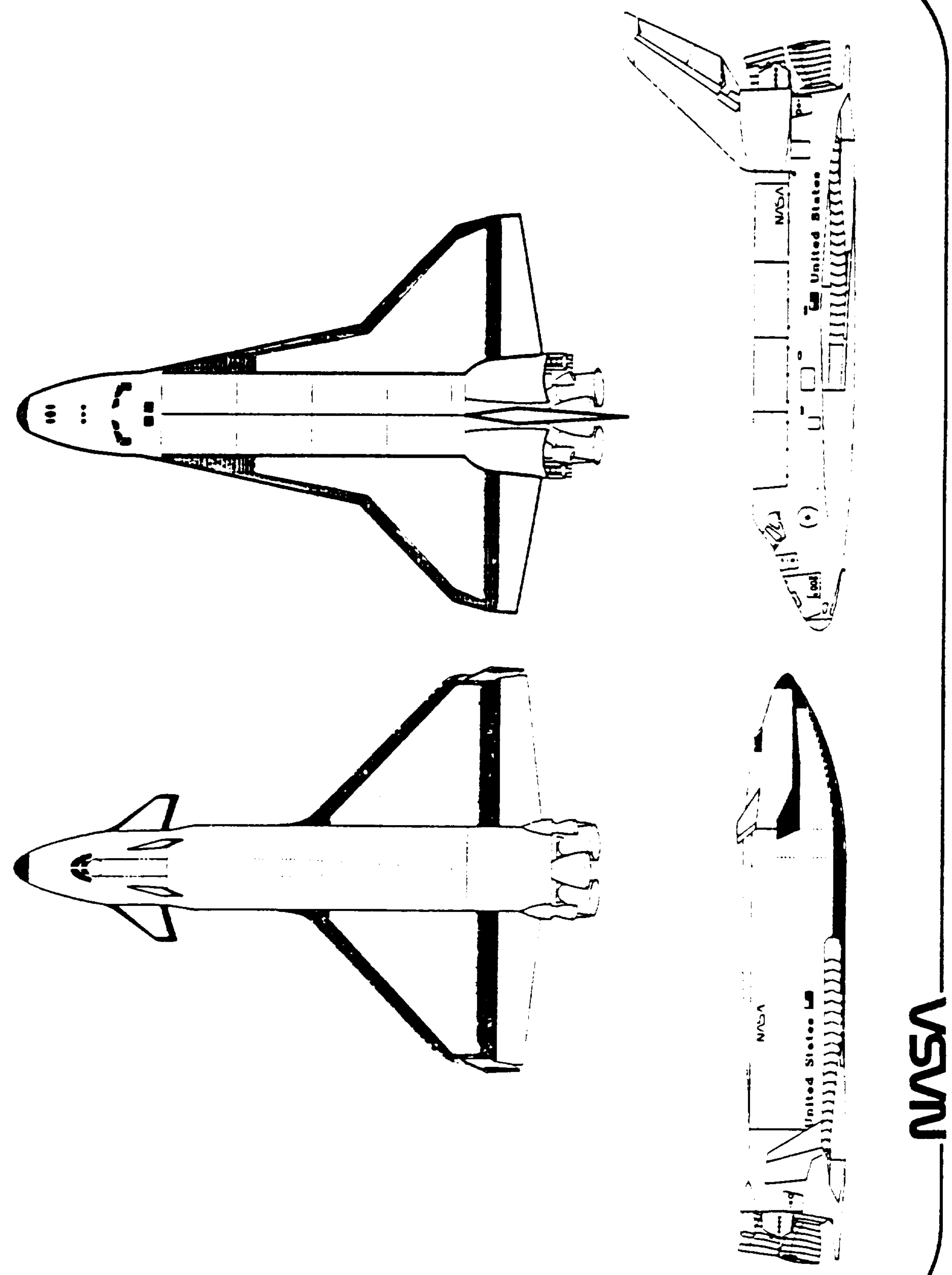
NEXT MANNED TRANSPORTATION SYSTEM



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NEXT MANNED TRANSPORTATION SYSTEM

Personnel Launch System

- Winged or blunt body
- Increased design margins
- ELV launched
- Configuration/size open
- Limited return cargo capability
- Up payload on cargo vehicle

NASA

PLS SIZING ISSUES AND CONSTRAINTS

- Number of personnel carried (4 - 16)
  - 8 (dual-trained Station/PLS flight crew)
  - 10 (dedicated PLS flight crew)
- Shuttle payload-bay constraints (CERV application)
  - 15-ft diameter sets PLS maximum body width (assumes folding fins)
- Booster capabilities (easterly for current ELV's)
  - Titan III -- 35,100 lbs
  - Titan IV -- 40,400 lbs
- Entry heating -- ACC, Shuttle HRSI tiles and FRSI blanket insulation
- Landing speed -- 175 knots

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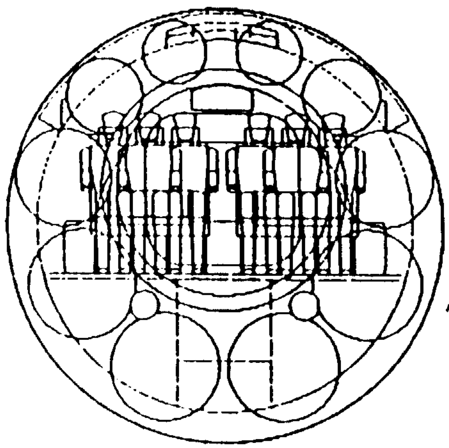
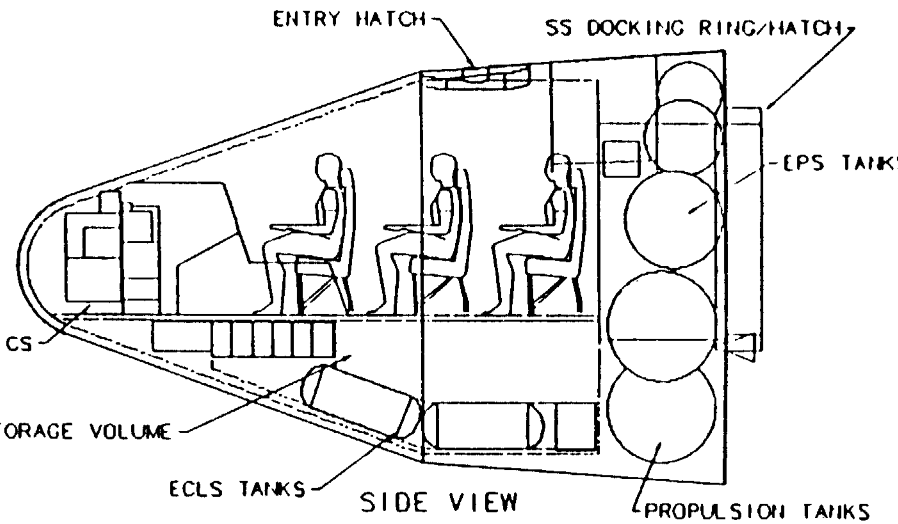
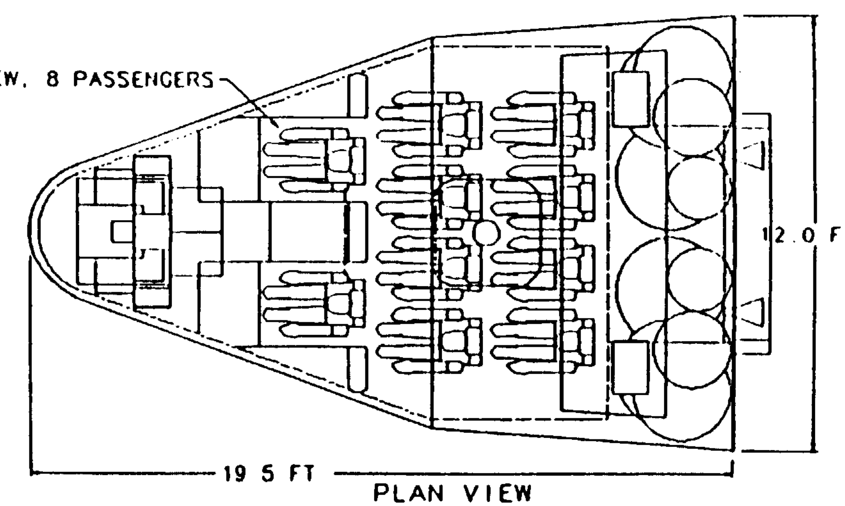
NEXT MANNED TRANSPORTATION SYSTEM

Personnel Launch System







PLS CONFIGURATION - BICONIC A

DRY WEIGHT	15,337 LBS
INERT WEIGHT	18,628 LBS
GROSS WEIGHT	23,023 LBS
SURFACE AREA	666 FT2
VOLUME	1,295 FT3

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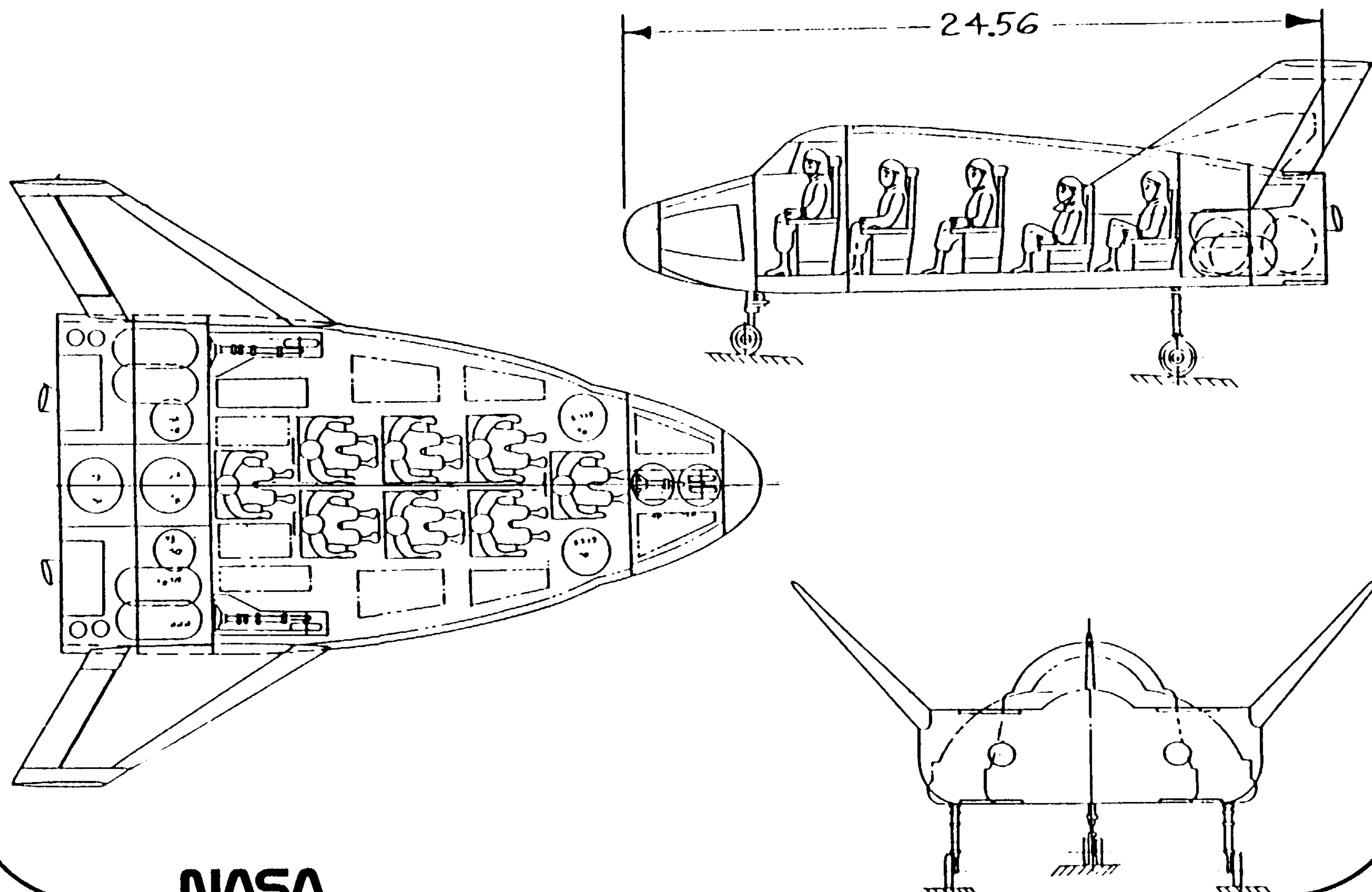
NEXT MANNED TRANSPORTATION SYSTEM

EIGHT MAN PLS

INBOARD PROFILE



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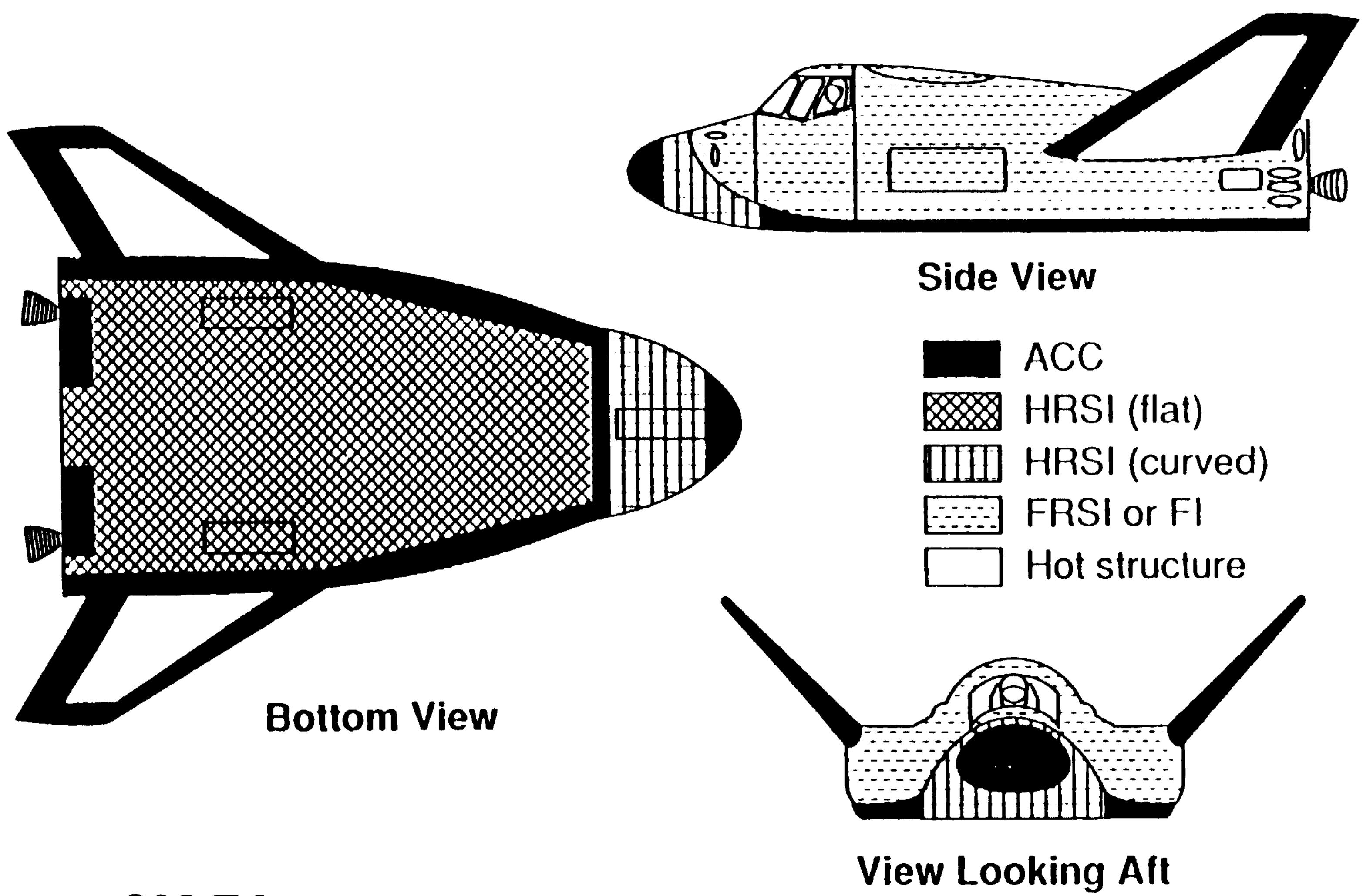
PLS THERMAL PROTECTION SYSTEM



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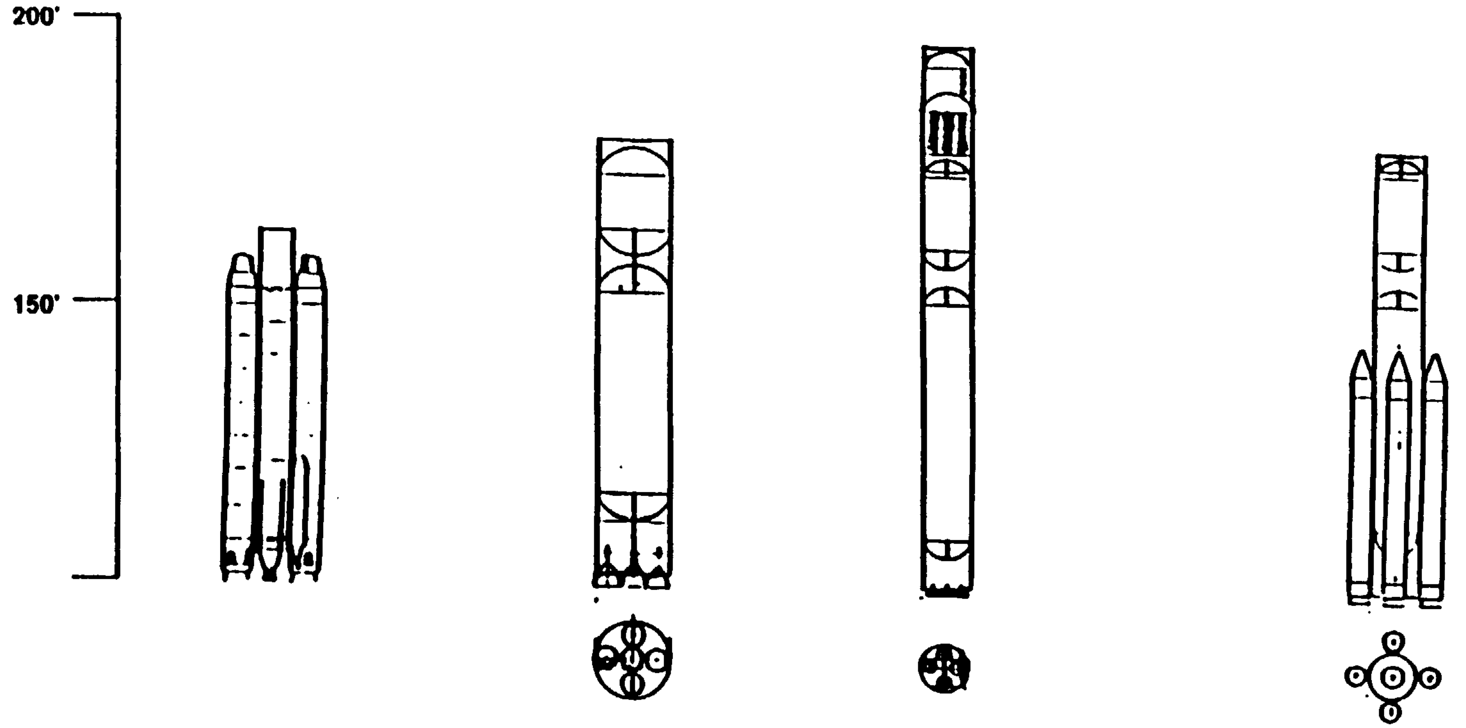
NEXT MANNED TRANSPORTATION SYSTEM

PLS LAUNCH VEHICLE CONCEPTS



	• TITAN IV	• ALS CORE 5 STME	• STS/LRB 4 STME	• STS/LRB 1 STME
	• 7 SEG OR SRMU	• STAGED 2/2	• NEW UPPER STAGE 6 RL-10	• 4 SOLIDS EQUIVALENT TO 1 STS/SRB
ETR/LEO PERFORMANCE (KLBS)	37 OR 48	52	42	38

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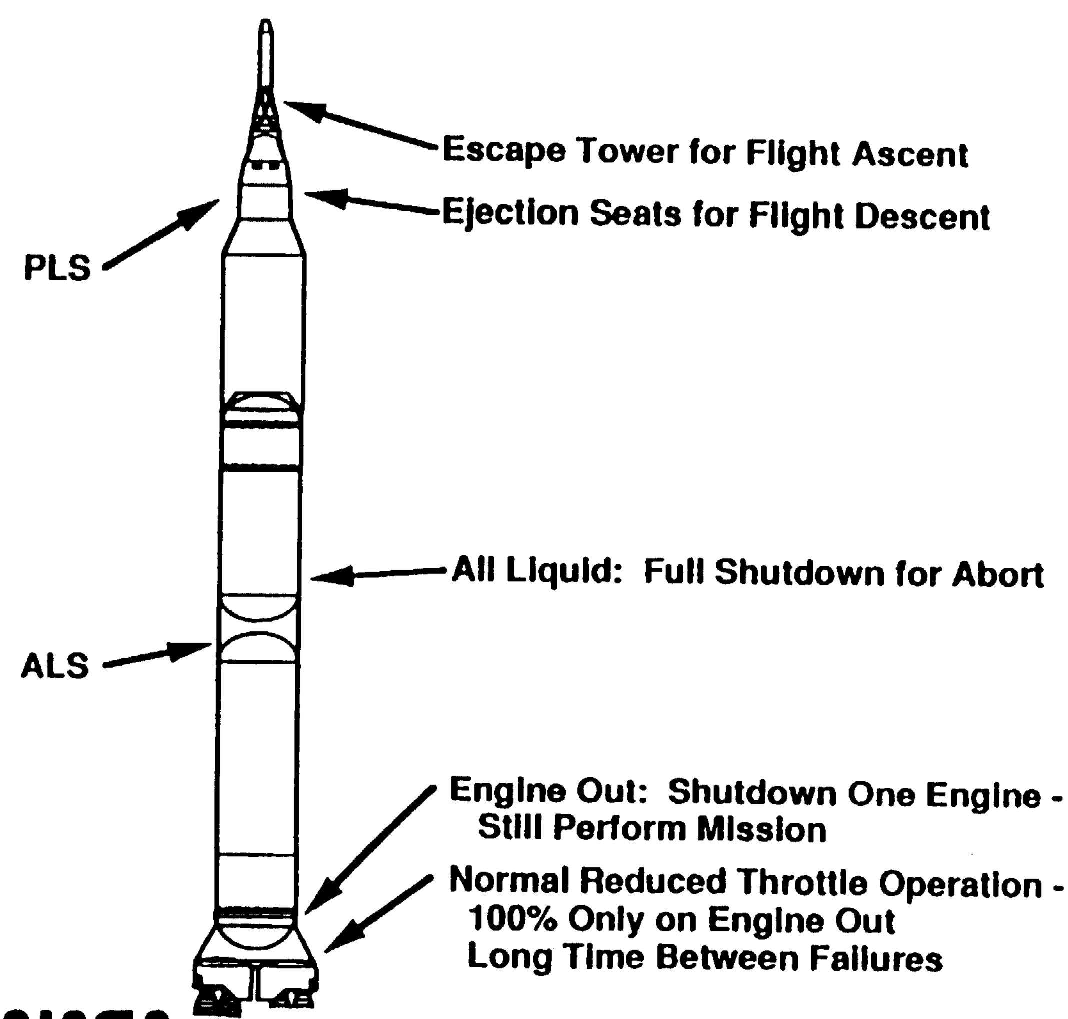
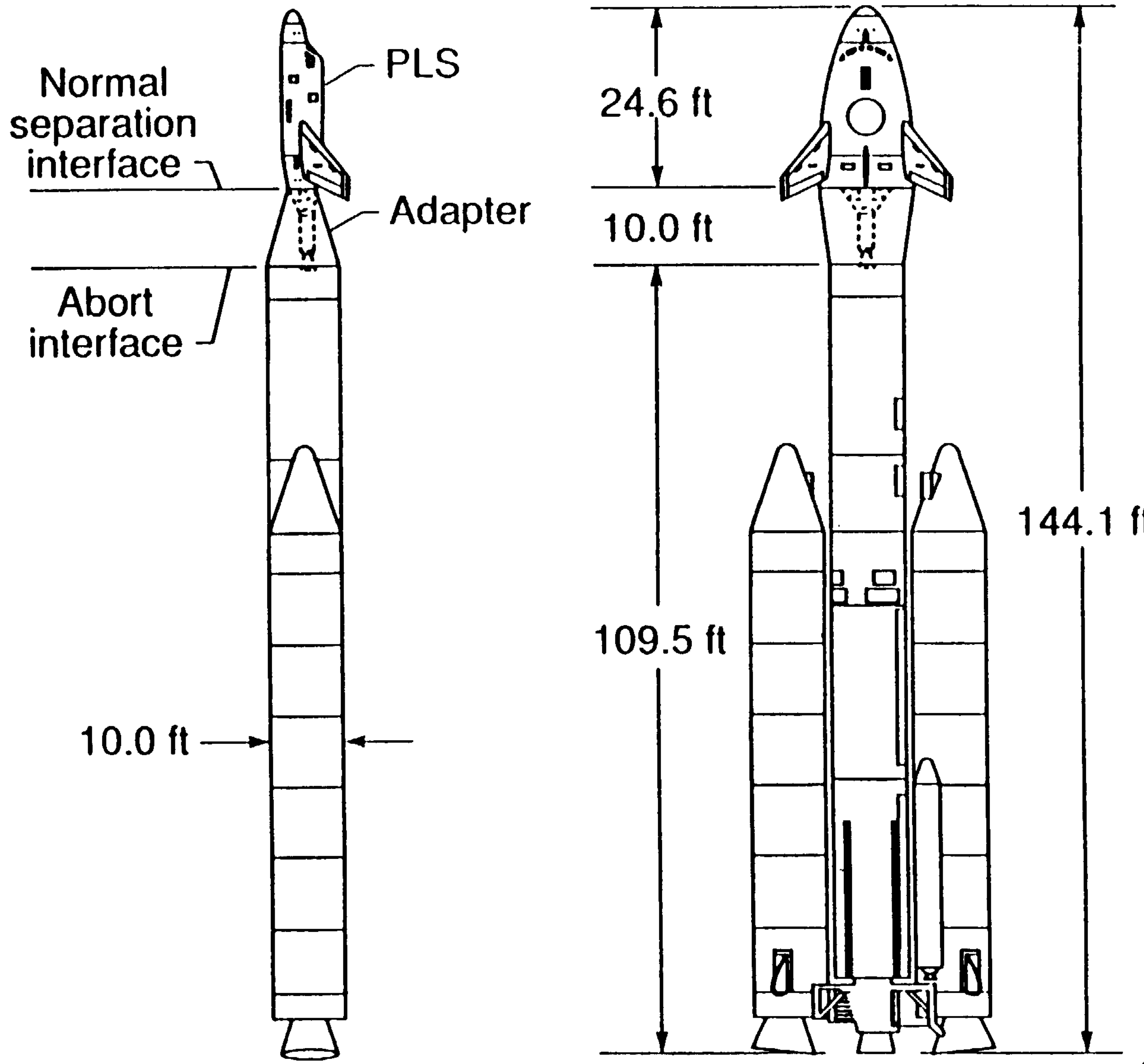
Reliability and Safety



NEXT MANNED TRANSPORTATION SYSTEM



NEXT MANNED TRANSPORTATION SYSTEM

Advanced Manned Launch System

- Exploit new technologies fully
- Improve design margins
- Configuration/size open
- People-only option available

NEXT MANNED TRANSPORTATION SYSTEM

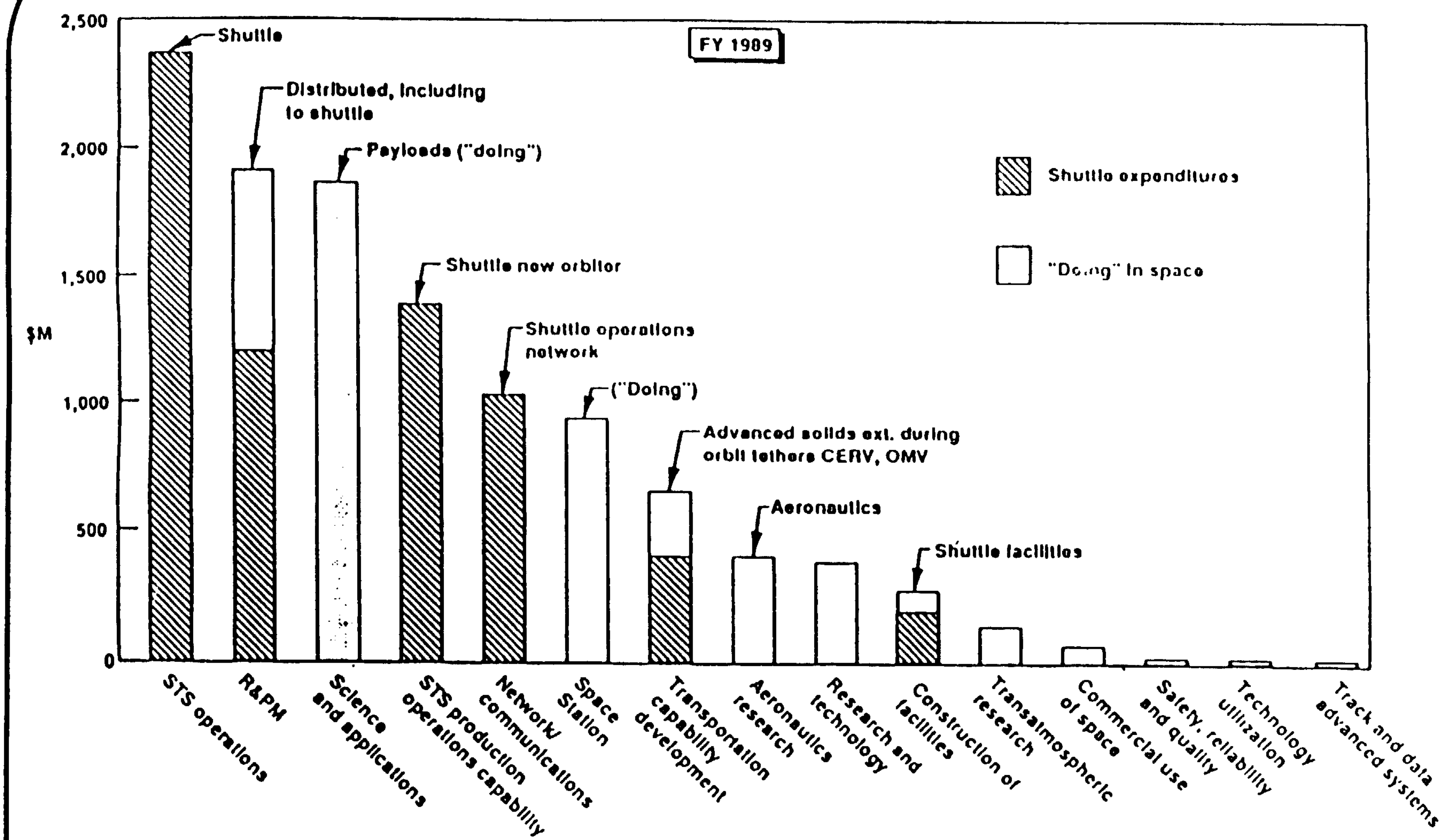
The Problem

- Cost of ownership of the shuttle is too high

The Solution

- New technology hardware can help
  - ALS
  - Code R Base
  - Pathfinder
  - IRAD
  - NASP
  - CSTI
  - SDI
  - Space Station Freedom
- Changes in operations methods can help
- New transportation systems can help

NEXT MANNED TRANSPORTATION SYSTEM

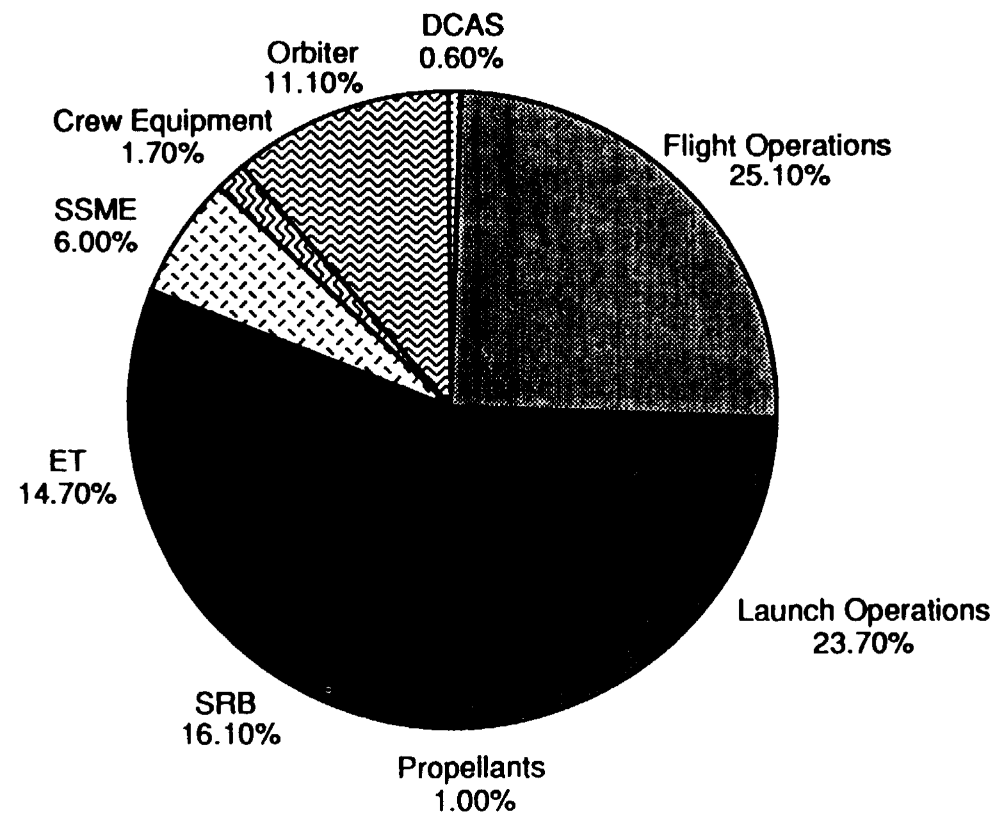


Shuttle funds dominate the NASA budget

NASA

NEXT MANNED TRANSPORTATION SYSTEM

STS Average Cost Per Flight (FY89-91) FY89 OMB Budget



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NEXT MANNED TRANSPORTATION SYSTEM

<u>Near-Term Goals</u>

1. Assured continuity of manned access to space
   - What happens if/when we lose another shuttle?
   - Consider additional or alternate vehicle

2. Assured transportation to orbit and assembly of Space Station Freedom
   - What if STS goes down during the assembly sequence?
   - A permanently manned Space Station implies continuity of support.

3. Improvements in overall crew safety
   - Improve current STS
   - New vehicle with better abort capability
   - Emergency crew rescue

4. Substantial reduction in operating cost

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NEXT MANNED TRANSPORTATION SYSTEM

Near-Term Issues

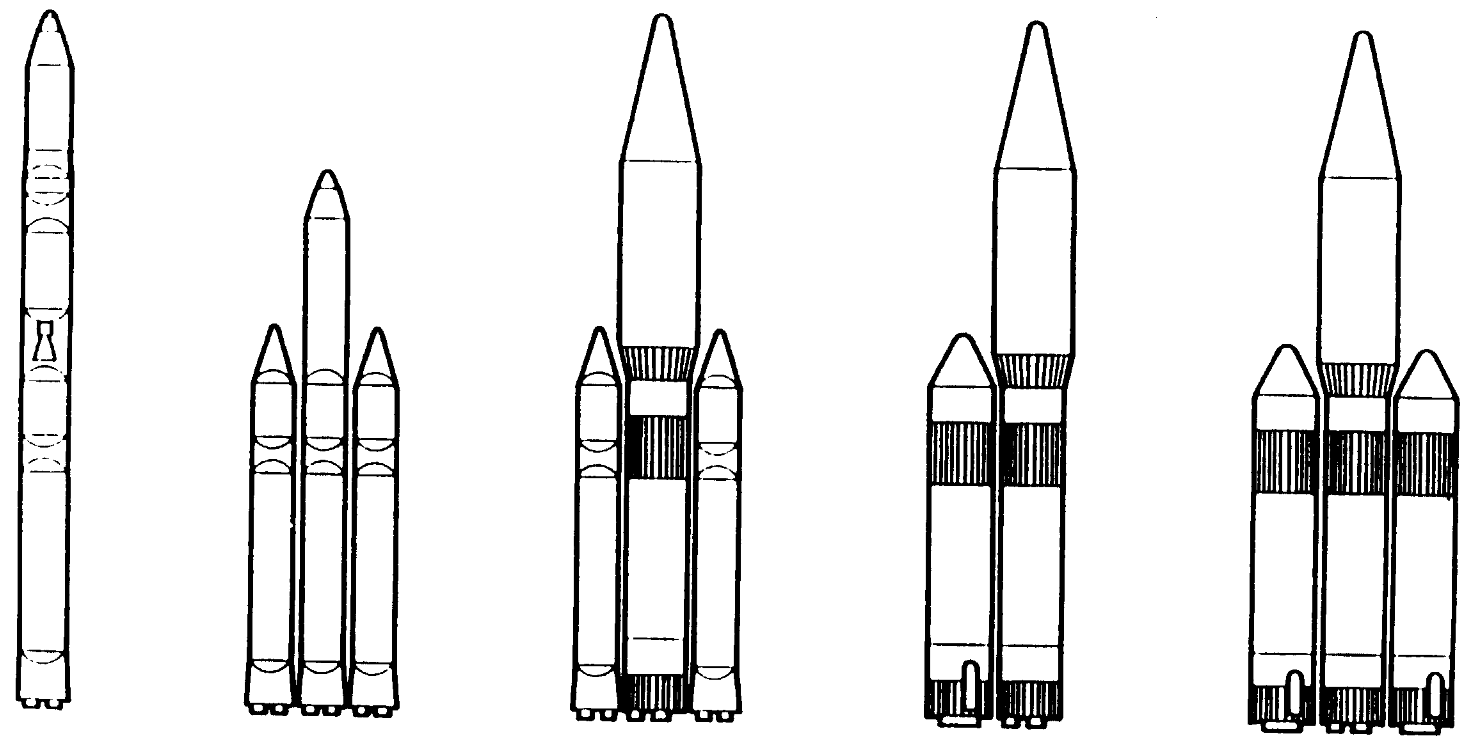
1. Can STS costs be reduced? (How? How much?)
2. Will DOD develop ALS, LRB, STME? (When?)
3. What should NASA do in the meantime?
   a. Design CERV to enable PLS? (Capsule or lifting body?)
   b. Optimum mix of STS/ELV's for cargo?
   c. Further investment in basic STS?
      - More orbiters, OV106, OV107, etc.
      - ASRM
      - Orbiter auto return
      - STS-C, C', Z
      - LRB
      - STME
      - Escape pod
4. What is impact of Lunar/Mars?

EACH ISSUE HAS LONG-TERM IMPLICATIONS.

MOST IMPORTANT FEATURE IS OPERATING COST.

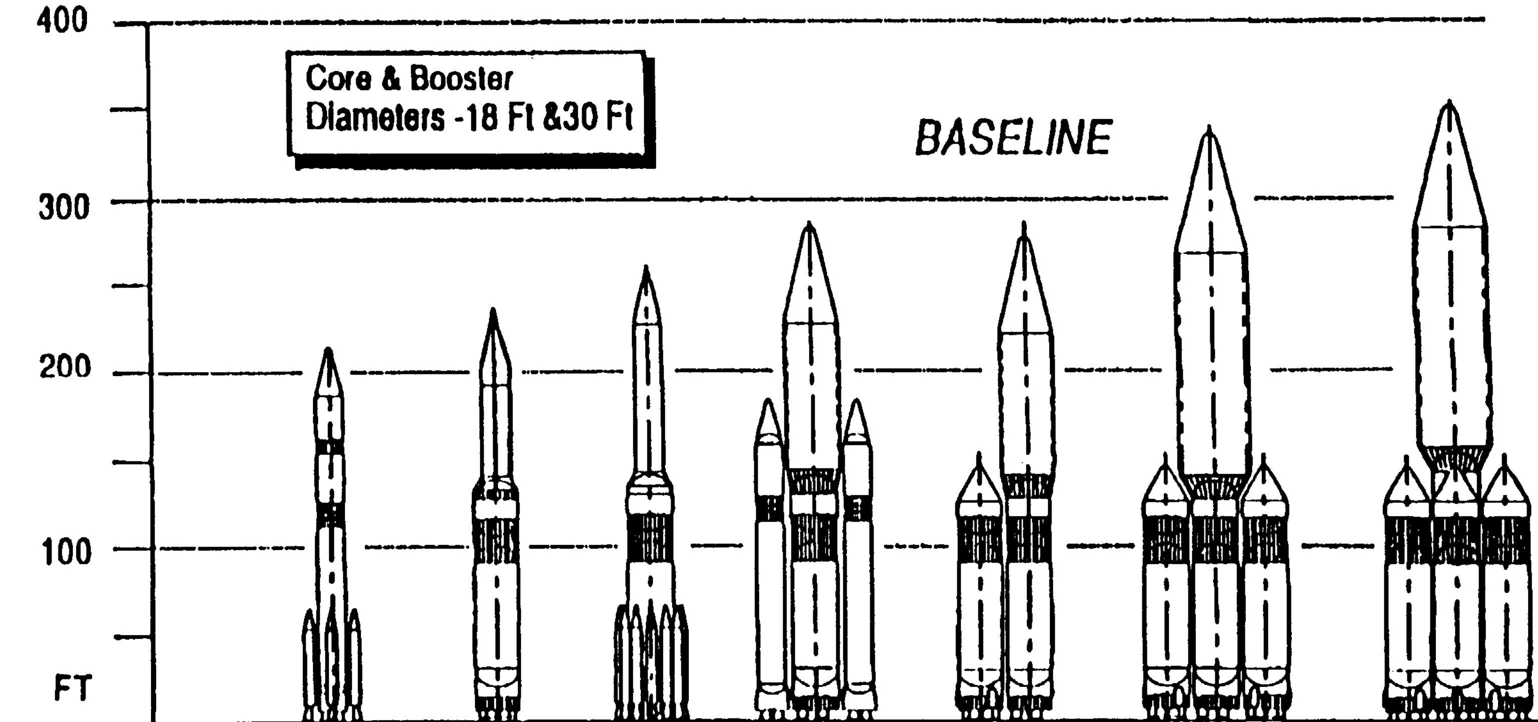
NASA

EXAMPLE ALS/LRB FAMILY



	LRB Stand-alone	LRB core + 2 LRBs	ALS core + 2 LRBs	ALS Baseline	ALS expanded model
LEO Payload	40 Klb	80 Klb	100 Klb	150 Klb	226 Klb

THE ALS FAMILY



	ALS-B(S)	ALS-L1.5	ALS-S12	ALS-BL2	*ALS-L*	ALS-L2	ALS-L4
RATED PAYLOAD	~10 KLB	~40 KLB	76 KLB	117 KLB	120 KLB	224 KLB	451 KLB
GLOW	TBD	TBD	3.52 MLB	3.47 MLB	3.56 MLB	5.31 MLB	9.13 MLB
BOOSTER PROP.	SOLID	O2H2	SOLID	O2H2	O2/H2	O2/H2	O2/H2

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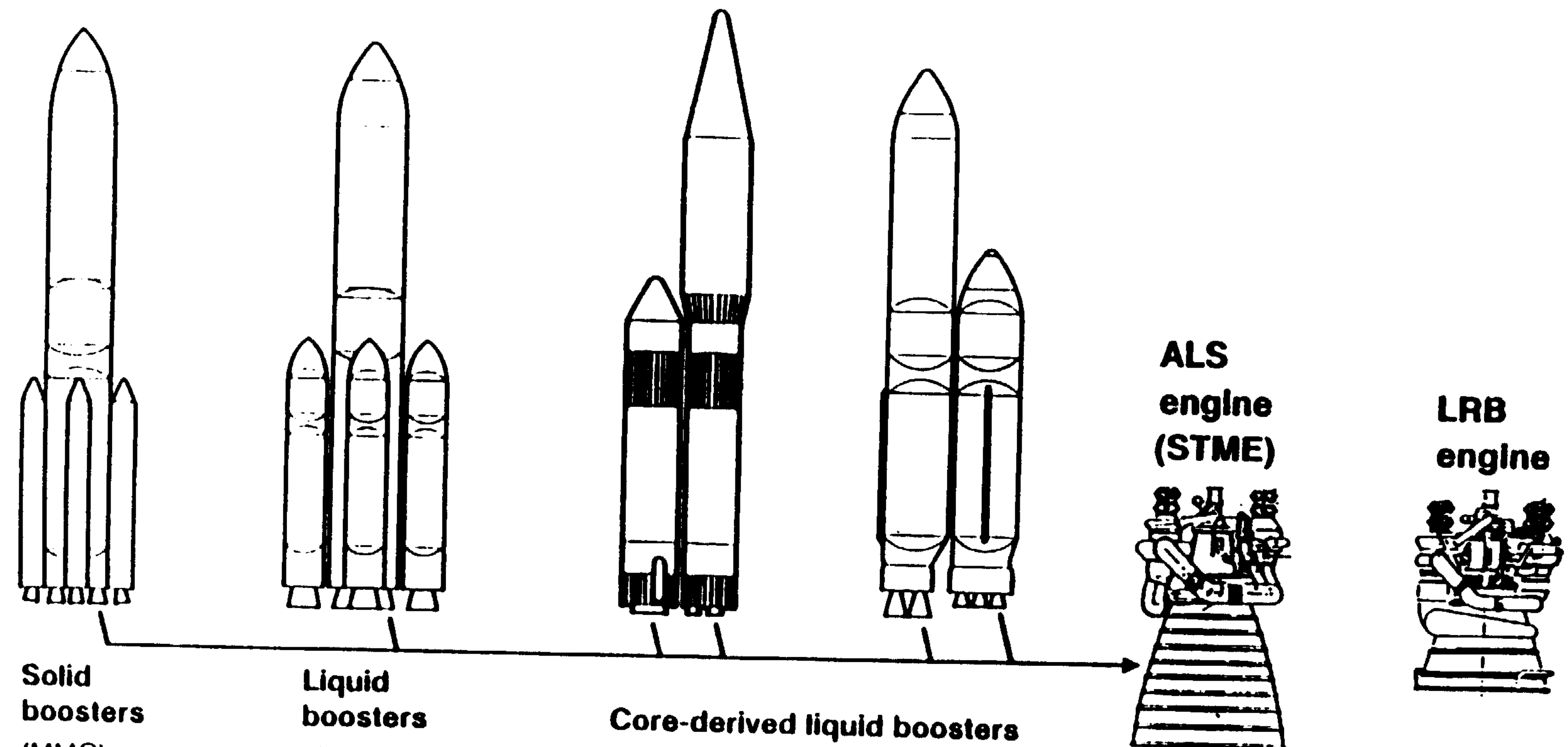
ALS CONCEPTS



	USAF	NASA
Propellants	O_2/H_2	O_2/H_2
Thrust (Klb-vac)	580	558
Chamber pressure (psia)	2250	2250
Expansion ratio: Core	62	–
(Booster)	39	20
Throttle range	N/A	+0% −25%

A common engine is feasible for ALS and LRB

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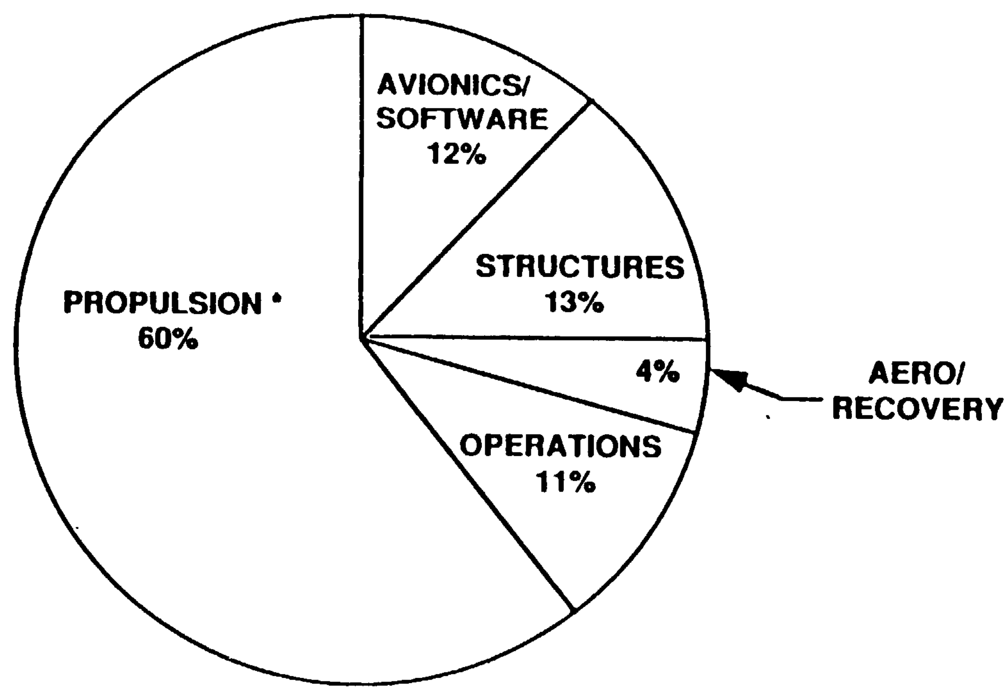
ALS Advanced Development Program
87 - 92 Program



* PROPULSION +
PROPULSION RELATED
EQUALS 67%

LIQUID ROCKET BOOSTERS OFFER SUPERIOR . . .

Safety — because of their ability to be shut down on command

Performance — greater than 30% performance improvement for STS

Environmental Cleanliness — primary exhaust product is steam

Versatility — well suited to a variety of applications

Launch Operations — 25% reduction in time-to-launch because LRBs are handled empty, without hazardous propellants

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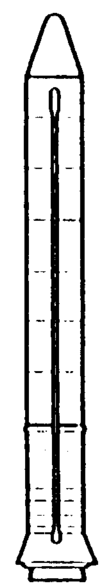
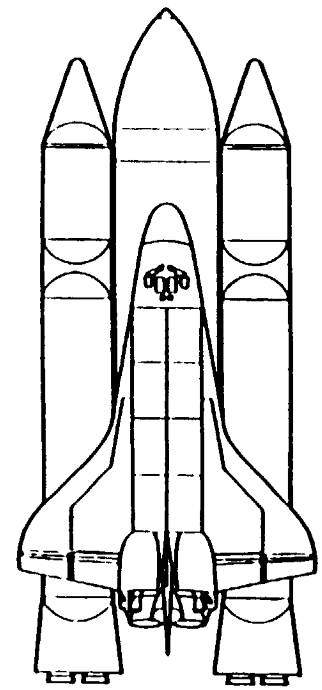
THE STS LIQUID ROCKET BOOSTER



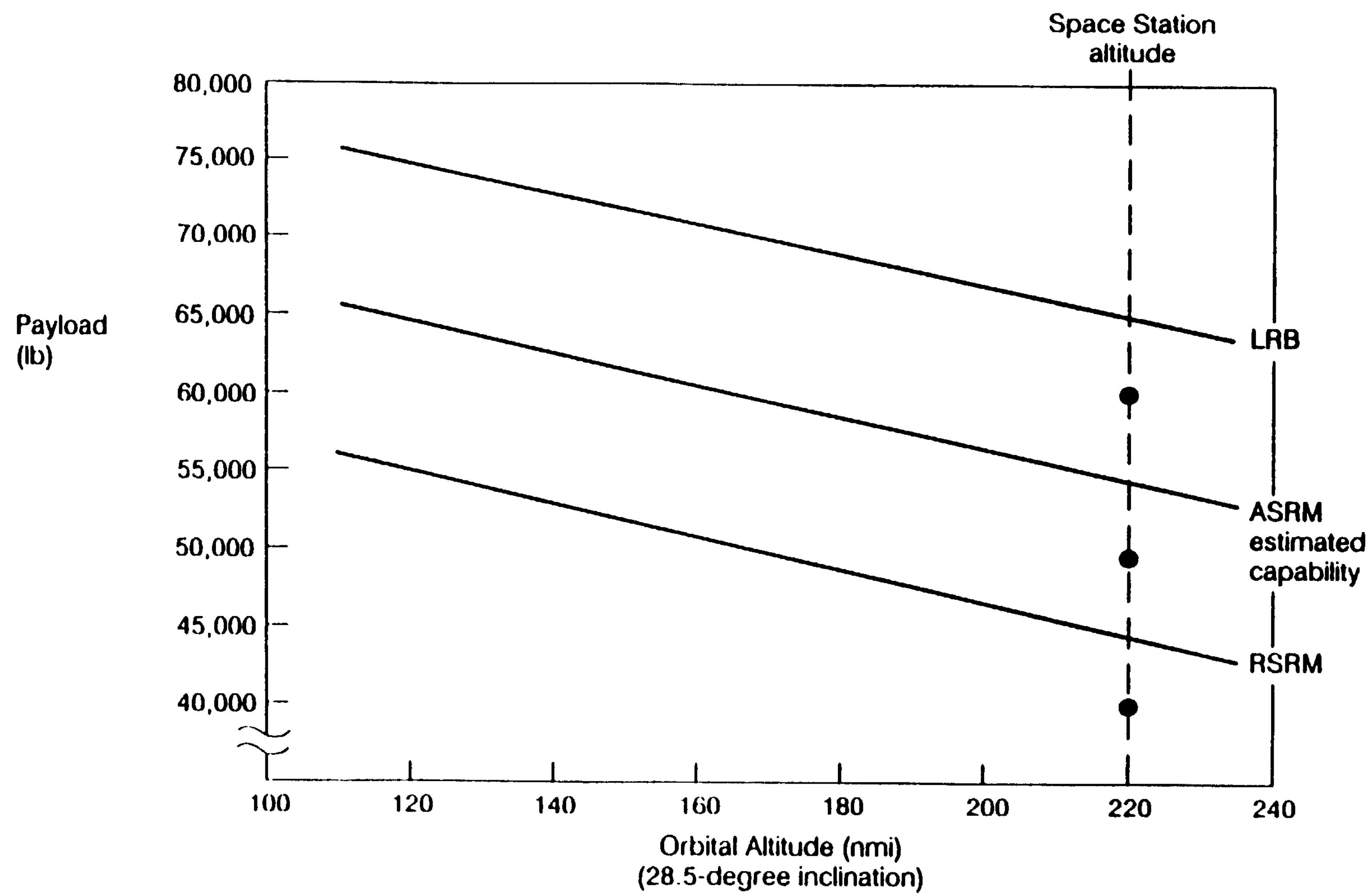


	SRB	LRB
Length (ft)	149	178
Diameter (ft)	12.2	18
Booster dry weight (lb)	146,000	122,000
Booster gross weight (lb)	1,250,000	821,000
Engine thrust at sea level (lb)	2,912,000	4 × 515,000

Features

- LH2/LO2 propellants
- 2219 aluminum tankage
- New low-cost, pump-fed engines
- 4 engines per booster
- Expendable (engines may be recovered)
- Existing technologies

SHUTTLE PERFORMANCE



NEXT MANNED TRANSPORTATION SYSTEM

Basic Requirements

For Future Manned Transportation Earth
To/From Earth Orbit

1. The system must be truly operational
   - Reliable
   - Resilient
2. Low Operating Cost

STS does not currently meet these criteria

Can a new system meet the criteria?

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NEXT MANNED TRANSPORTATION SYSTEM

Reliability

Definition: Probability that a flight will proceed successfully from launch through landing.

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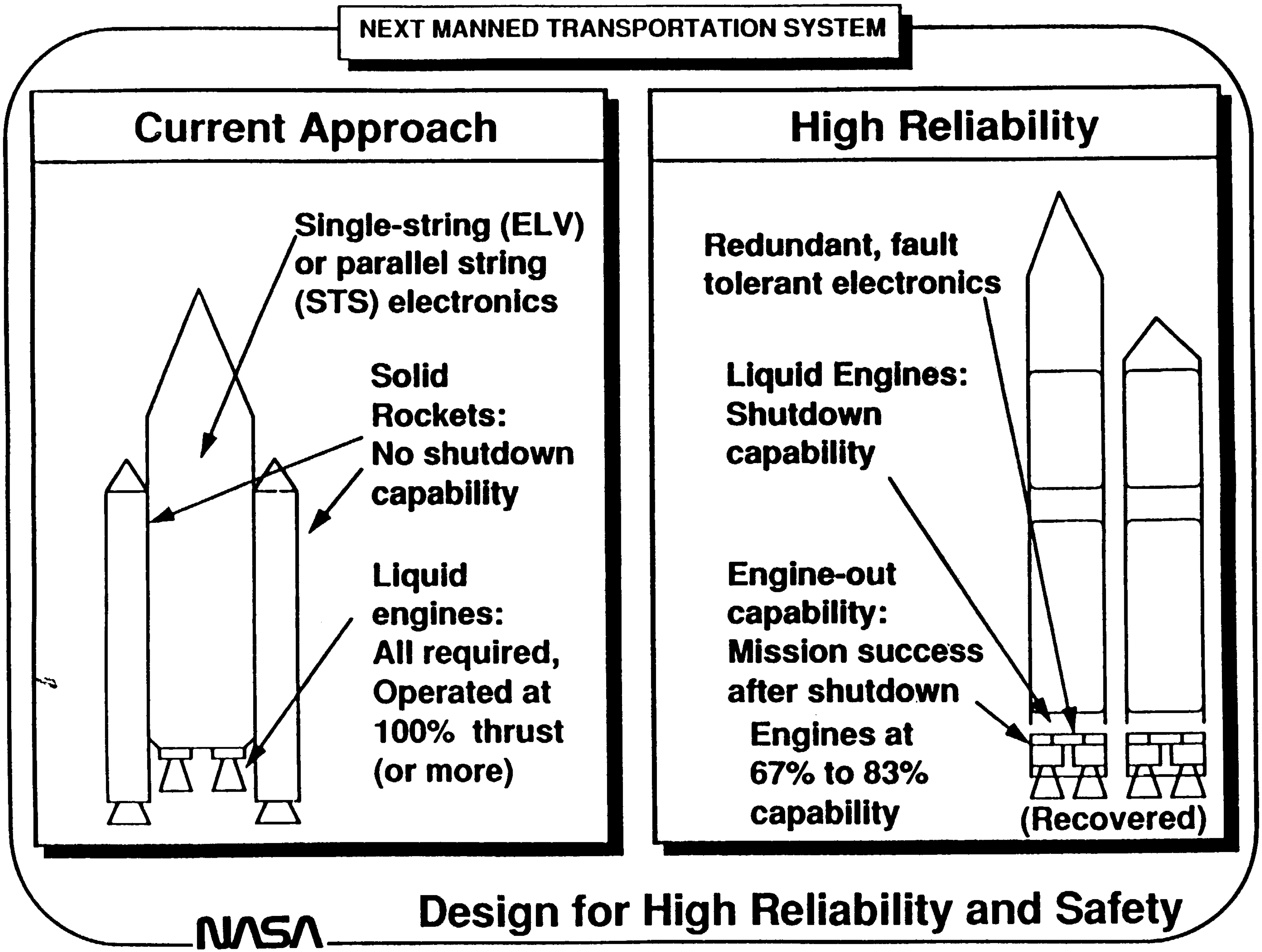
NEXT MANNED TRANSPORTATION SYSTEM
Current Approach
Single-string (ELV) or parallel string (STS) electronics
Solid Rockets: No shutdown capability
Liquid engines: All required, Operated at 100% thrust (or more)
High Reliability
Redundant, fault tolerant electronics
Liquid Engines: Shutdown capability
Engine-out capability: Mission success after shutdown
Engines at 67% to 83% capability
(Recovered)
NASA
Design for High Reliability and Safety

NEXT MANNED TRANSPORTATION SYSTEM

Resiliency

Definition: Ability of the system to readily recover from effects of flight failures and resulting stand-down times

NASA

NEXT MANNED TRANSPORTATION SYSTEM

Resiliency/Interchangeability

- Ability to guarantee assured access to Space Station Freedom is required during its assembly and operations/maintenance
- Probability of shuttle loss resulting in long down-time is presently high
- Methods to guarantee resiliency are required; i.e.,
  - An alternate manned launch vehicle
  - Design interchangeable propulsion sytems for shuttle and shuttle derivatives

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NEXT MANNED TRANSPORTATION SYSTEM

Definition of Man-Rating

- A man-rated space system incorporates those design features and requirements necessary to accommodate human participants.
- It provides the capability to safely conduct manned operations, including safe recovery from any credible emergency situations.
- Man rating is the process of evaluating and assuring that the hardware and software can meet prescribed, safety-oriented design and operational criteria.
- It is an integral part of the design, development, verification, management, and control process.
- It continues throughout the operational life of the system.

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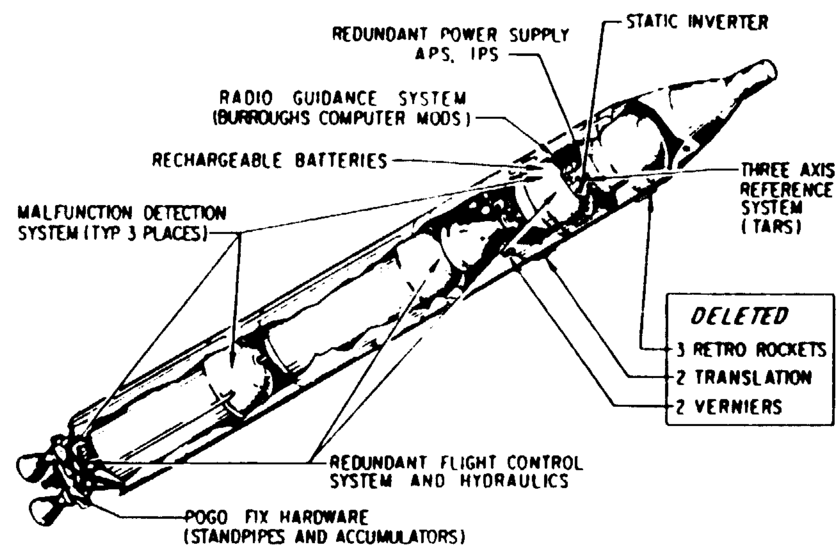
NEXT MANNED TRANSPORTATION SYSTEM

Man-Rating the Titan II

Major hardware changes between the Titan II and the Gemini Launch Vehicle consisted of those items which enhanced mission success or crew safety, permitted vehicle compatibility with the spacecraft, and accomplished weight savings.

- The transition section between the spacecraft and launch vehicle
- The radio guidance system
- The electrical power supply
- Deletion of rocket motors
- Addition of Pogo hardware
- Redundant flight control
- Malfunction detection systems

NEXT MANNED TRANSPORTATION SYSTEM



Gemini Launch Vehicle configuration and modifications.

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NEXT MANNED TRANSPORTATION SYSTEM

Conclusions

1. Current STS performs multiple functions extremely well
   - But does not meet top-level criteria
2. Operational support of Space Station places extra level of requirements for resilience in manned space transportation
3. NASA should anticipate loss of another shuttle
   - Inherent reliability limitations and frequent flights make it "not if, but when"

NEXT MANNED TRANSPORTATION SYSTEM

Conclusions

4. Operations costs dominate total yearly costs
    - For all cases, current systems & new systems
    - DDT&E relatively small
    - Potential large return for small investment
5. Achieving low-cost operation
    - Special purpose vehicles to match function
    - Emphasis on operability during design
    - Integrate STS/SSF/lunar programs
    - Incentives for NASA & contractor management

NEXT MANNED TRANSPORTATION SYSTEM

Conclusions

6. Breakthroughs needed in both reliability and total cost of operations
   - Current options may or may not meet criteria
     - Advanced technology may be required
   - Ongoing manned spacecraft design activity needed to identify & exploit breakthroughs
7. Timing of shuttle replacement is not clear
   - Operations cost analysis of alternate systems needed
     - Include total yearly costs of current and alternate systems

NEXT MANNED TRANSPORTATION SYSTEM

Why STS Operations Goals Were Not Achieved

- Early STS budget cuts necessitated de-emphasis on operations
  Examples: 1) Orbiter payload bay doors
  2) Onboard fault isolation

- Very complex design
  Examples: 1) SSME turbo blade inspection
  2) Orbiter thermal protection system
  3) SRB segment assembly

- Design and operations were not closely integrated

NASA

NEXT MANNED TRANSPORTATION SYSTEM

Life-Cycle Costs

Definition: Nonrecurring costs of development and procurement

+

recurring costs of maintenance and operations.

NEXT MANNED TRANSPORTATION SYSTEM

Technologies/Guidelines to Reduce Operational Costs

- Simplified interfaces and systems
  - Especially propulsion and payload accommodations
- Onboard checkout/fault isolation
- Automated work control/problem status system
- Minimal weather constraints
- Simple, durable thermal protection system
- Performance margins

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NEXT MANNED TRANSPORTATION SYSTEM

IS A NEW MANNED SYSTEM NEEDED? **YES**

- STS too costly
- Manned system should have first stage abort capability
- Obsolescence
- Assured manned access needed
- Functional requirements are changing

- People to/from orbit	- New system more efficient
- Cargo to orbit	- Cargo vehicles more efficient
- Orbital experiments	- SSF more efficient
- Return cargo	- Requirement is soft
- Maneuvering & servicing	- Servicing economics are soft

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NEXT MANNED TRANSPORTATION SYSTEM

IS A NEW MANNED SYSTEM NEEDED?

NO

- STS satisfies most requirements
  - People to/from orbit
  - Cargo to orbit
  - Orbital experiments
  - Return cargo
  - Orbital maneuvering and servicing
- Capitalize on large investment
- Scarce DDT&E funds needed for SSF and Lunar/Mars
- Paper systems always cheaper than real systems
- High operating costs are independent of system configuration

NEXT MANNED TRANSPORTATION SYSTEM

Improvement is Possible

- To make a better/safer shuttle
  - Shuttle evolution
  - LRB's which allow first-stage abort
- To improve environmental impact
  - LRB
- To plan for assured manned access to space
  - PLS
  - ALS
  - More Orbiters
- To reduce high Ops costs
  - LRB
  - Shuttle evolution

NASA

NEXT MANNED TRANSPORTATION SYSTEM

Choosing Among Alternatives

Shuttle
ASRM
Shuttle-C
Shuttle Derived Heavy Lift

→ Solid Rocket Booster Choices

Shuttle Evolution
LRB

ALS
PLS

→ Liquid Rocket Booster Choices

NEXT MANNED TRANSPORTATION SYSTEM

One Possible Choice

- Evolve Shuttle
  - Add LRB
  - Limit crew size so first stage abort is possible
  - Use for launching high-valve payloads, down payloads, and for backup for large crews
- Develop ALS for modular HLLV capability for routine cargo launches
- Develop PLS with first-stage abort for routine crew launches

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NEXT MANNED TRANSPORTATION SYSTEM

Avionics Requirements

Safety Improvements

- Manned rating
  - Malfunction detection and abort implementation
- High-reliability systems/hardware
- High mission success for both manned and cargo

Operations Cost Improvements

- Onboard checkout and fault isolation
- Improve ground turnaround operations
- Low-cost systems/hardware

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MANNED SPACE TRANSPORTATION SYSTEMS

Manned transportation is required in four areas:

1. Earth-to-orbit arena
2. Onorbit arena
3. Transfer systems arena
4. Planetary surface systems arena

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MANNED SPACE TRANSPORTATION SYSTEMS

1. Earth-to-Orbit Arena
   - Unmanned systems
   - Manned systems
     - "Routine" access to Earth orbit
       - Current System
         - Shuttle
       - Future Systems
         - Shuttle Evolution
         - PLS
         - AMLS
         - NDV's
     - Rescue/Emergency Access ETO
       - Shuttle Rescue
       - CERV
       - Alternate Access Options
       - International Alternatives

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MANNED SPACE TRANSPORTATION SYSTEMS

2. Onorbit arena
    - Unmanned systems
    - Manned systems
        - Permanently Occupied Facilities
            - SSF Hab Modules
            - SSF Lab Modules
        - Man-tended Facilities
            - EDO
            - MTFF
            - ISF
        - EVA Activities/Environments
            - Obiter Payload Deploy/Retrieval
            - SSF Assembly
            - Lunar/Mars Vehicle Assembly
            - Servicing Activities
                - from Orbiter or Other Nodes
            - Emergency EVA Activities

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MANNED SPACE TRANSPORTATION SYSTEMS

3. Transfer systems arena
   - Unmanned systems
   - Manned systems
     - Activities in Earth Orbit
       - Manned OMV's
     - Transfer Between Earth & Moon
       - Manned STV's
       - Lunar Landers
       - Rescue Options
     - Transfer Between Earth & Mars
       - Variable Gravity Facility (VGF)
       - Zero Gravity Vehicle Options
       - Transfer Options Between Moon & Mars
       - Rescue Options

MANNED SPACE TRANSPORTATION SYSTEMS

4. Planetary surface systems arena
   - Unmanned systems
   - Manned systems
     - Mobile Systems
       - Surface EVA Systems
       - Land Rovers
       - Aerial Systems
       - Mobile Temporary Shelters
     - Stationary Systems
       - Habitats
       - Laboratories
       - Shops, Processing Facilities
       - Permanent Emergency Shelters

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CRITICAL HUMAN FACTORS DESIGN CONSIDERATIONS

CONSUMABLES REQUIREMENTS

Food, Water, Oxygen, Clothing, Tools/Supplies, Emergency Supplies, EVA Systems

ENVIRONMENTAL REQUIREMENTS

- Volume per Person
- Gravity Environment
- Workload Conditions
  - Mission Requirements
  - Housekeeping Requirements
- Orientation Cues
- Odor Control/Requirements
- Temperature Control/Requirements
- Radiation & Contamination Detection & Protection
- Off-Duty Activities Requirements
- Exercise Requirements
- Crew Comfort/Ergonomics Requirements
- "Ease of Operation" Requirements
- Communications
- Windows & Other Visuals
- Waste Management (Personal & Trash)
- Personal Hygiene Requirements
- Emergency Procedures/Options
- Safe Havens
- Medical Requirements
- Storage Requirements
- Psychological Environment
  - Crew Mix
  - Training/Counselling
  - Color Requirements
- Repair/Maintenance Requirements
- Recycling Requirements

CRITICAL HUMAN FACTORS DESIGN CONSIDERATIONS

ENGINEERING FACTORS

Structures; Materials; Systems Engineering (Avionics, Power, Thermal, ECLSS, etc.); Crew Size Requirements; Radiation & Impact Protection; Payload & Storage Requirements; Environmental Requirements

GROUND SUPPORT REQUIREMENTS FOR MANNED SPACE SYSTEMS

Launch Support

Recovery/Return Support

Mission Planning Support

Mission Control Support

Communications & Tracking Support

Medical Support

Training Support

Support from Unmanned Systems

Research & Technology Development Support