



# Integrated Systems Health Management Architecture

10 April 12

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# Integrated Systems Health Management



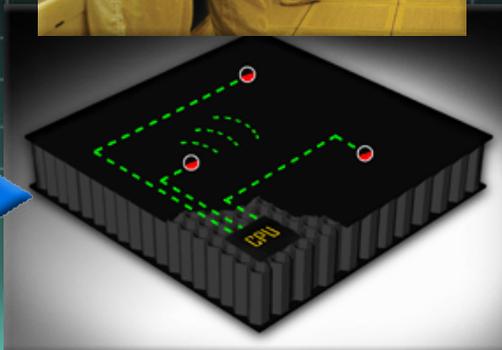
Any system that collects, processes and manages health data to assess the current condition of an aerospace vehicle and determine its ability to perform a given mission.



Determine Ability to Perform Mission



Assess Damage



Detect Damage



# Definition



- **State** - the condition of a person or thing, as with respect to circumstances or attributes: *a state of health.*
- **ISHM** - the determination of the overall state of a system through the conversion of data into information and knowledge, and the utilization of this state information and knowledge to influence the system's operation.

***“Using system's state (health) as a control variable for efficient mission operations”***

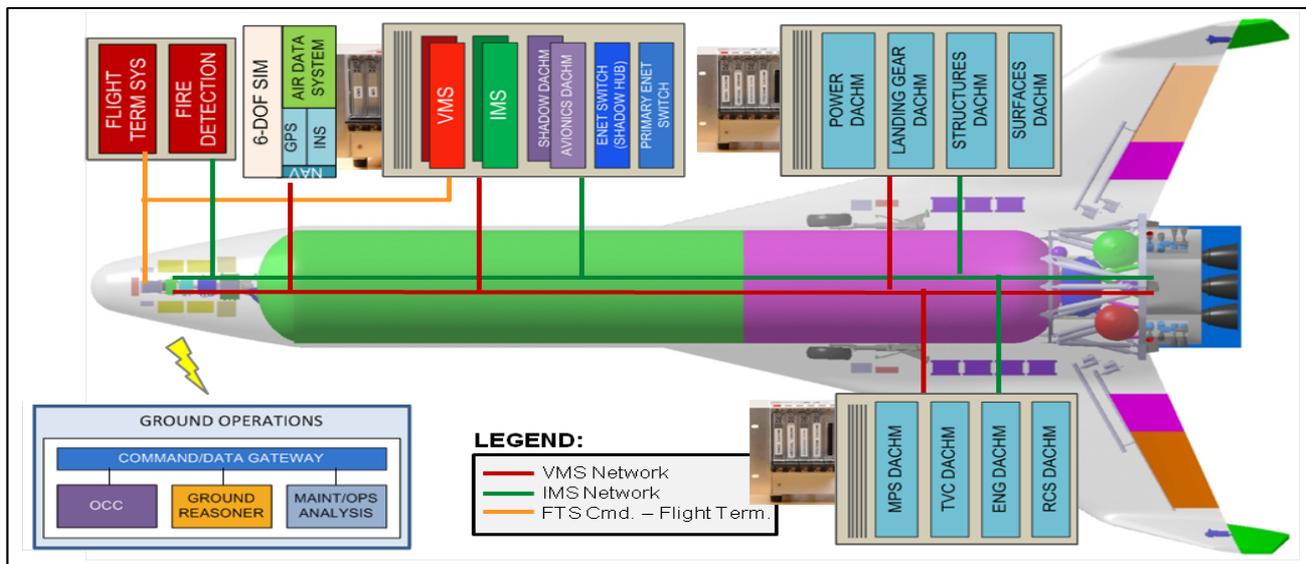
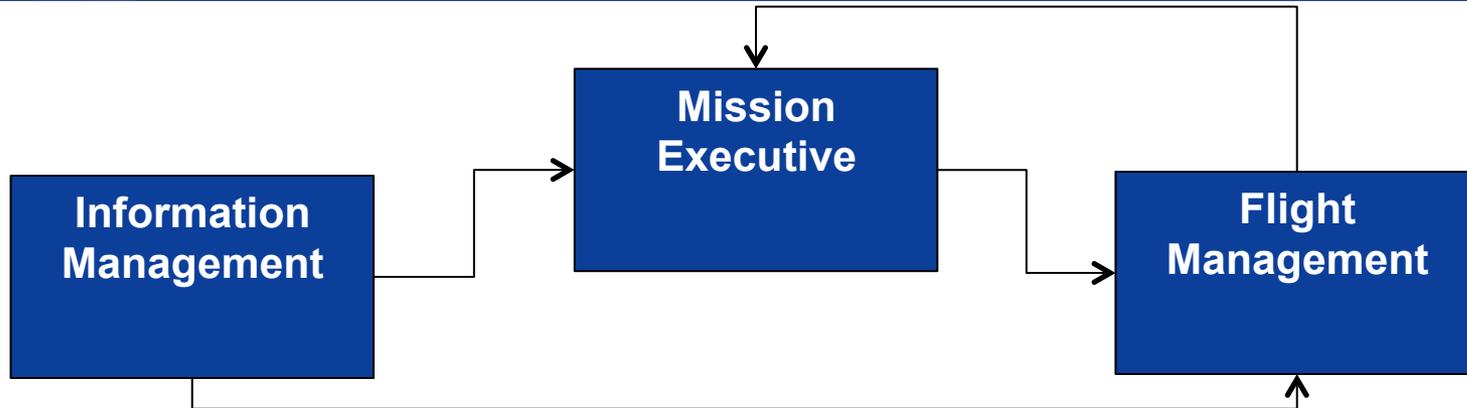


# ISHM Attributes





# Top Level Functional Architecture





## Descriptions

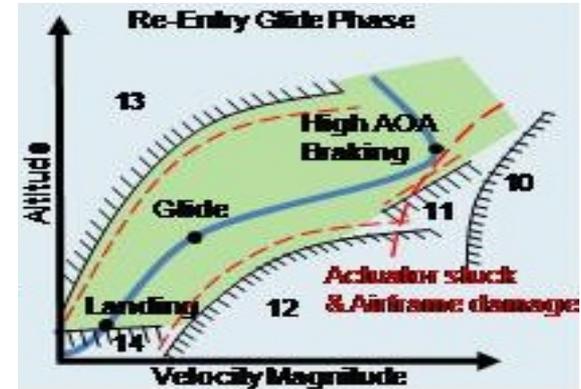
- **Information Management**– This function is responsible for acquiring and storing data related to the vehicle's state in regard to the vehicle position, orientation, performance, health, capability. Using this information, the Information Management function is also responsible for generating advisories which change vehicle state and capability.
- **Mission Executive** – The Mission Executive function is an umbrella term for planning and managing the mission. It considers and integrates the state of the system and its capabilities, designs the mission and specific tasks, constructs an action plan and handles variations and contingencies.
- **Flight Management** – The function that instigates and regulates action. Performs trajectory generation, guidance and control processing necessary to fly the vehicle.



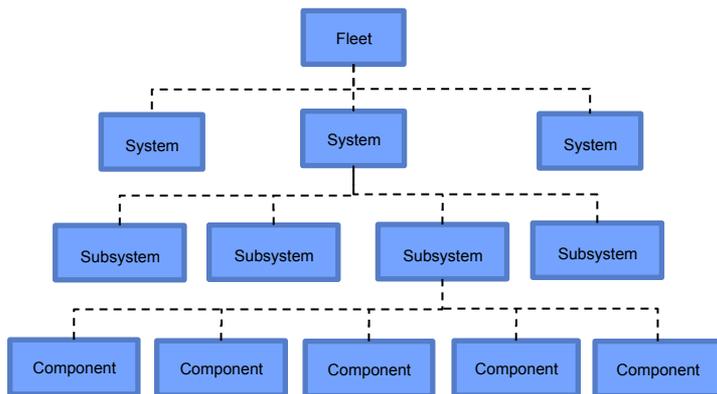
# Architecture Characteristics



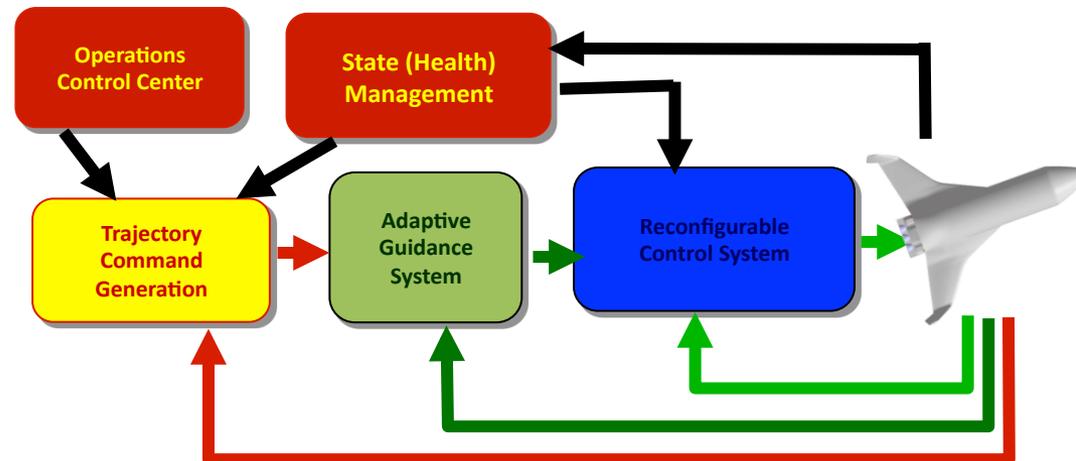
- Hierarchical Structure
- Distributed Processing
- Multi-level Reasoning
- Operates in Real-time
- Generates Actionable Information



Flight Envelop



Hierarchy Configuration



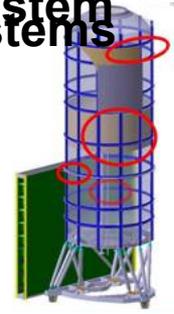
Adaptive Guidance & Controls



# Architecture Operation



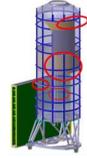
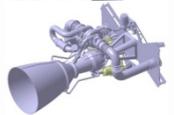
With knowledge of the vehicle's capability, the flight control system can adapt its control of its estimation of the vehicle's current capability to the vehicle management system and the mission retask the vehicle to allow for its continued observations of its system performance are observed an unexpected event in a subsystem, the information management system determines the overall system status by combining level information from a system-level information system



t Control  
tuator

Engine

Structural  
Tank

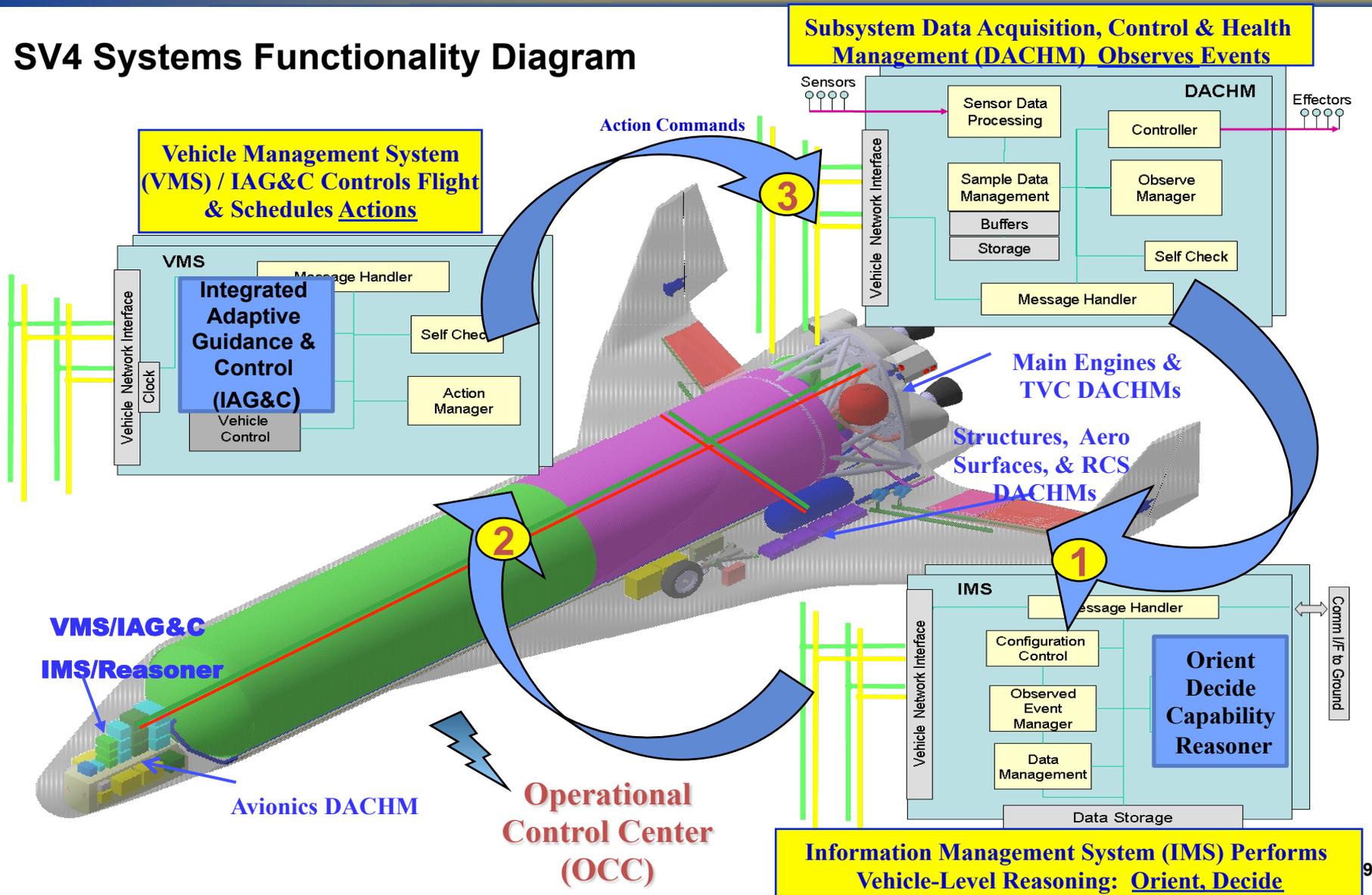




# Department of Defense Architecture Framework (DoDAF)



## SV4 Systems Functionality Diagram





# Space Access Technology Goals

*- Incremental Steps to Future Vision -*



- Rapid turn 48 hrs
- 3X lower ops cost
- Vehicle reliability 0.995
- All Wx availability 90%
- 250 Sortie Airframe
- 100 Sortie Propulsion & Systems

- Rapid turn 24 hrs
- 10X lower ops cost
- Vehicle reliability 0.999
- All Wx availability 95%
- 500 Sortie Airframe
- 250 Sortie Propulsion & Systems

- Rapid turn 4 hrs
- 100X lower ops cost
- Vehicle reliability 0.9998
- All Wx availability 98%
- 1,000 Sortie Airframe
- 500 Sortie Propulsion & Systems

**BASELINE**  
EELV, Shuttle,  
Aircraft Ops



**Near Term**



**Mid Term**



**Far Term**





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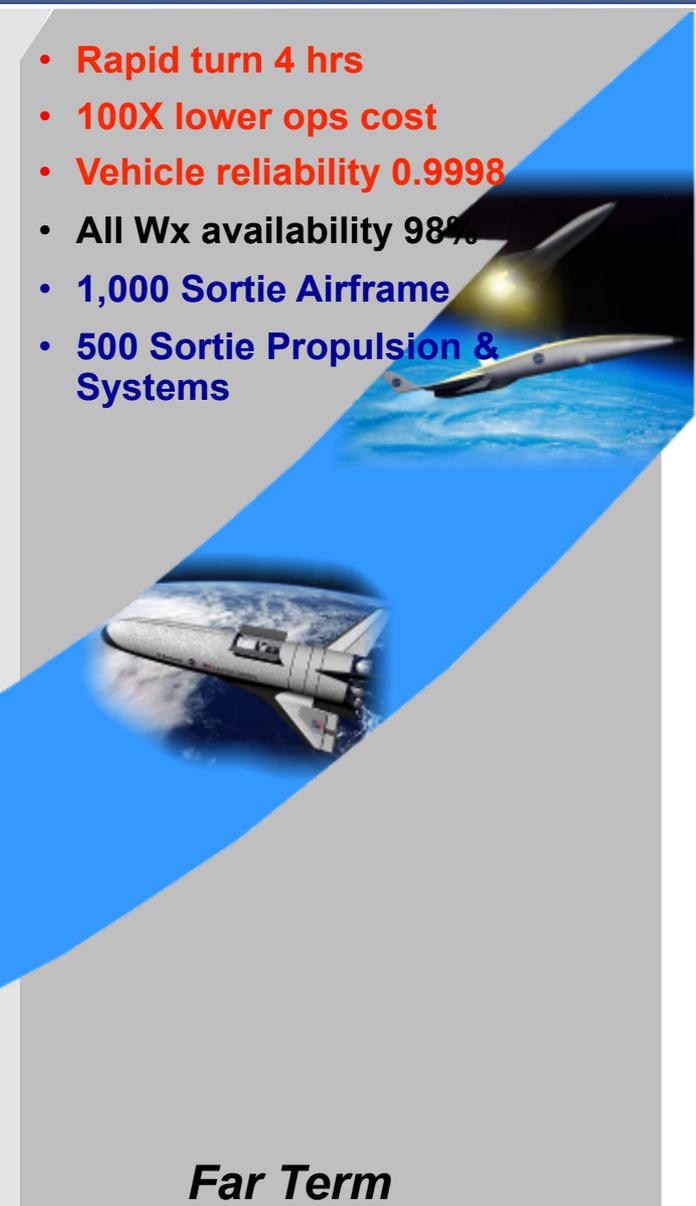
**Near Term**



**Mid Term**



**Far Term**

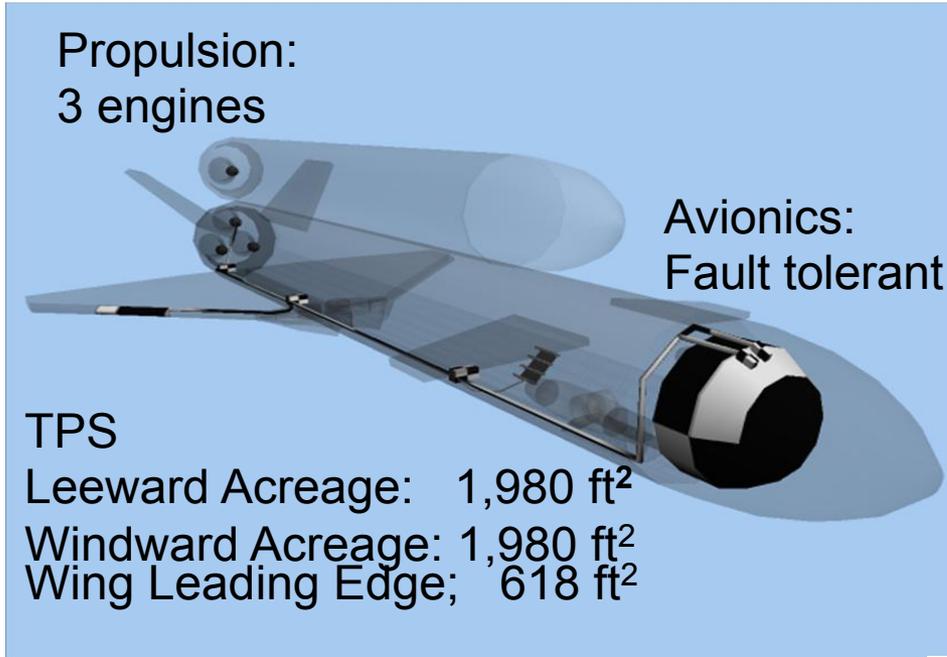




# ISHM Architecture Design

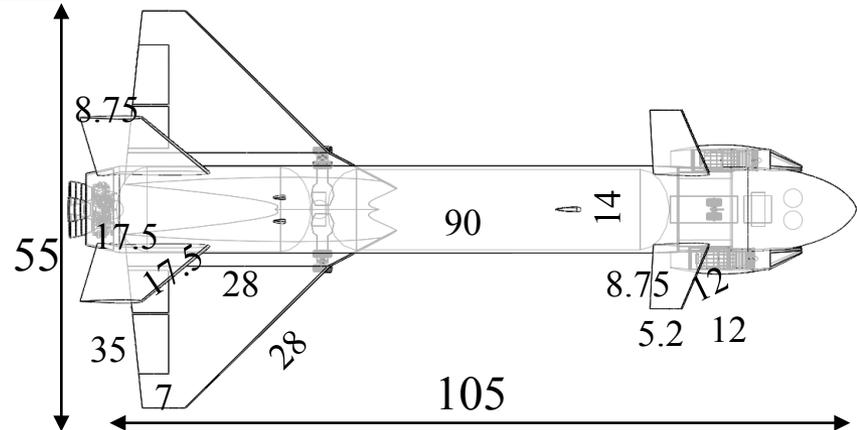
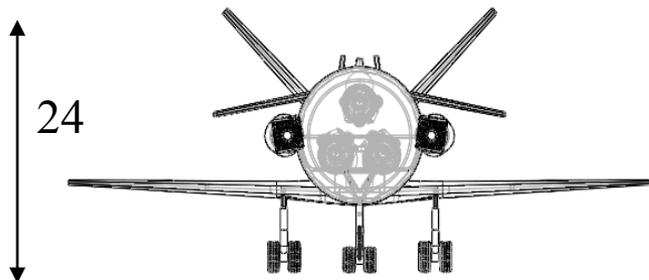


## Baseline Vehicle



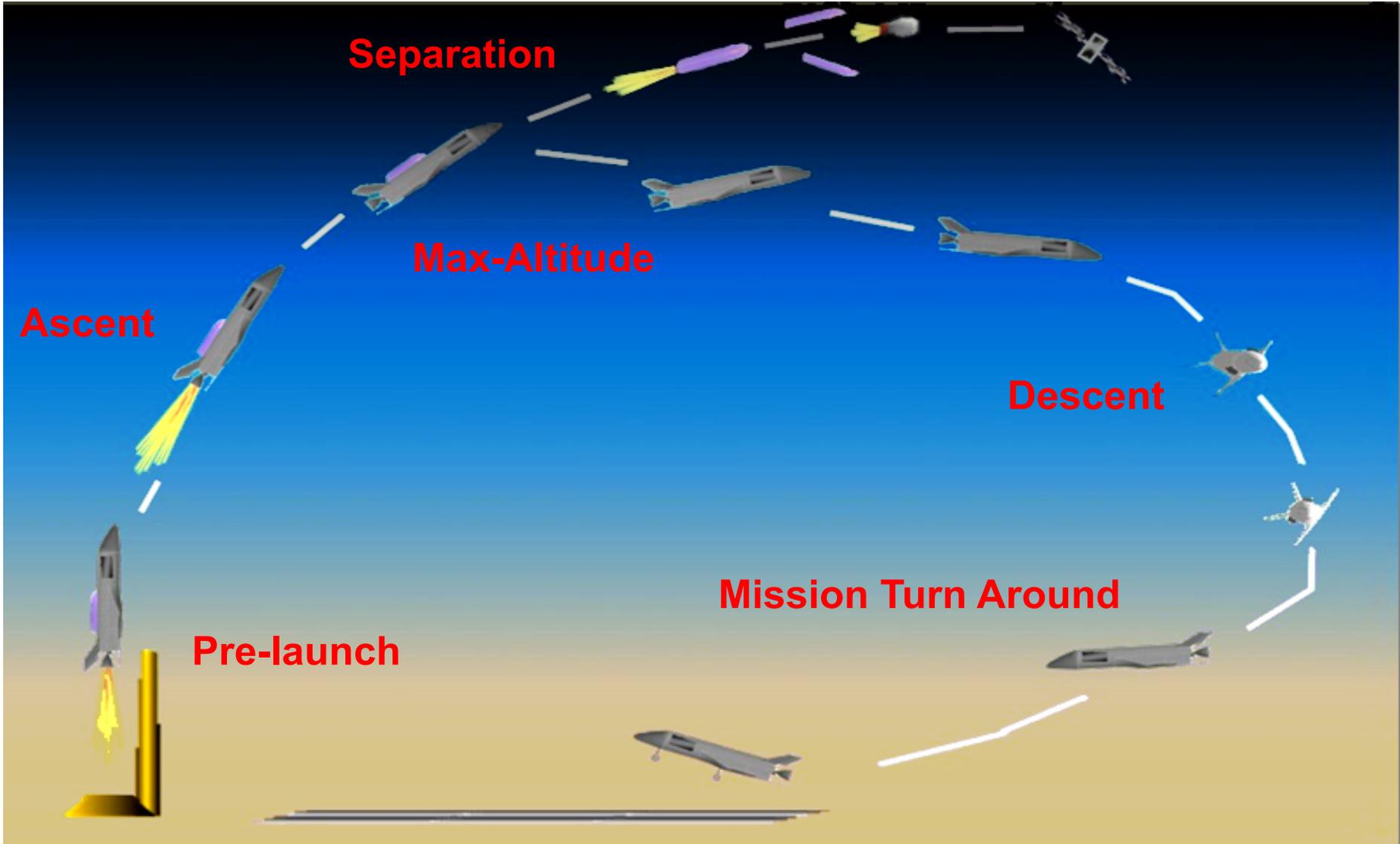
Item	Value
Gross Weight	710,750 lb
Dry Weight	78,870 lb
Stage Gross Weight (w/o payload)	568,980 lb
Ascent Mass Ratio	2.96
Flyback Mass Ratio	1.15
Ascent Mixture Ratio	2.7
Length	105 ft

Chose non-proprietary vehicle





# Baseline Vehicle Concepts of Operations





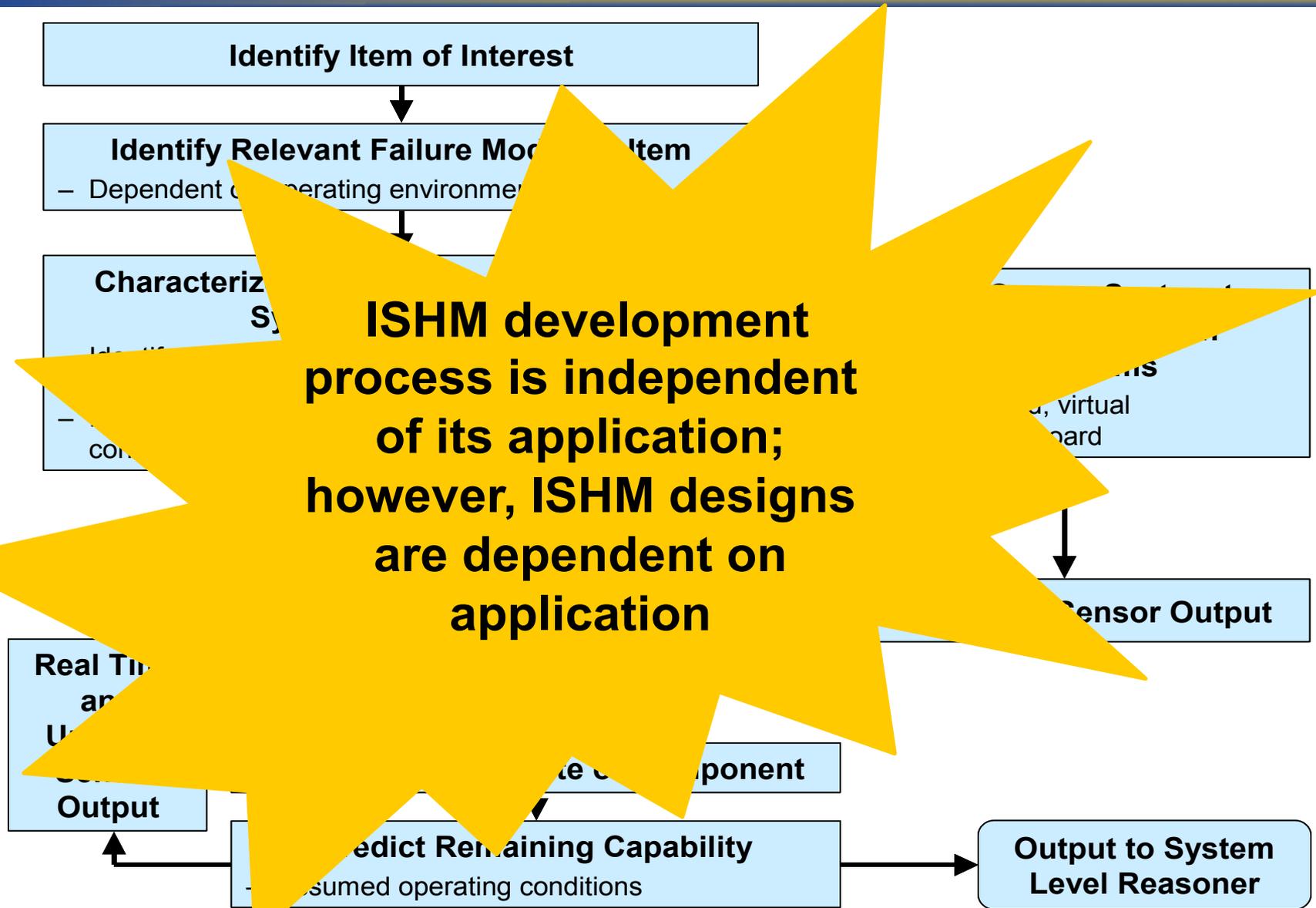
# Failure Mode Effects & Criticality Analysis



	Total	Safety	Mission	
1 Structure, Airframe, LM	2.02E-01	3.00E-04	2.30E-03	allocated
Structure, Airframe, LM	2.00E-01	3.00E-04	3.00E-04 2.00E-03	predicted
2 Thermal Protection System, LM	1.22E+00	1.50E-03	2.15E-02	allocated
Thermal Protection System, LM	1.22E+00	5.00E-04	5.00E-04 1.00E-03	predicted
3 Landing Gear	5.14E-02	4.00E-04	1.40E-03	allocated
Landing Gear	2.08E-01	3.32E-04	3.32E-04 5.85E-04	predicted
4 Propellant Tanks and Feed	2.02E-01	2.00E-04	1.70E-03	allocated
Propellant Tanks and Feed	2.06E-01	1.86E-05	6.23E-04 8.23E-04	predicted
5 Main Propulsion Engines	2.01E-01	5.00E-04	1.00E-03	allocated
Main Propulsion Engines	2.28E-01	9.79E-04	2.48E-03	predicted
8 N2, Purge, Vent, Pressurization	2.02E-01	1.60E-04	2.16E-03	allocated
N2, Purge, Vent, Pressurization	2.01E-01	9.37E-05	2.54E-04 8.04E-05	predicted
9 Thermal Management System, ECS	1.72E-01	1.00E-04	2.10E-03	allocated
Thermal Management System, ECS	2.01E-01	9.14E-06	9.14E-05 1.83E-04	predicted
10 Electrical Power System	2.42E-01	2.00E-04	2.20E-03	allocated
Electrical Power System	2.69E-01	6.07E-06	9.48E-04 4.70E-02	predicted
11 Avionics	2.04E-01	4.00E-04	4.40E-03	allocated
Avionics	2.43E-01	7.00E-07	3.08E-04 2.14E-02	predicted
12 Actuation, Honeywell	4.45E-01	2.40E-04	5.24E-03	allocated
Actuation, Honeywell	1.55E-01	2.31E-04	9.80E-03 2.32E-04	predicted



# ISHM Development Process



**ISHM development process is independent of its application; however, ISHM designs are dependent on application**



# Subsystems Ground Test

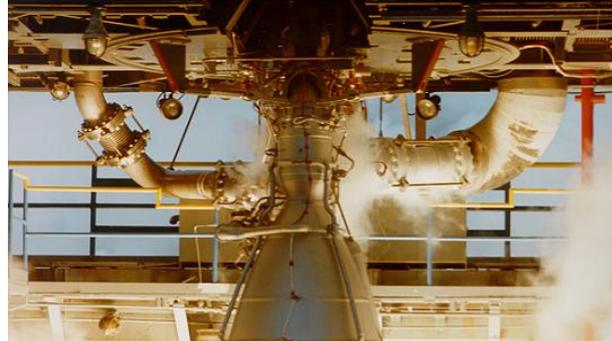


## TPS HM Requirements:

Sensors Output: 64 channels  
 Sensors Wt: 0.002 lbs  
 Data Rate: 800 Bytes/s



**3'x3' Inconel TPS Panels**



## Propulsion HM Requirements:

Sensor Output: 47 channels  
 Sensors weight: 50 lbs  
 Data Rate: 42 KBytes/s

**Aerojet's NK3343 Engine**

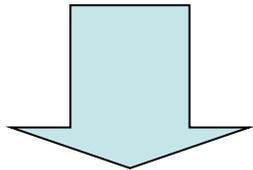
## Avionics Requirements

Reliability  
 Expandability/Re-configurability  
 Implementation Flexibility  
 Low life cycle cost

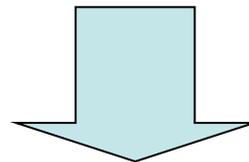


**Honeywell's Modular Avionics**

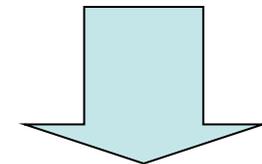
## Subsystems Failure Modes



**Impact Damage**



**Fuel Contamination**



**Avionics Failure**

### Structures Health Mgt

Time	Tile	Force (lb)	Status
11:12:23:10	5	150	Red

Sim Interface

### Propulsion/ Engine

Sim Interface

### VMS

Common Simulation Infrastructure

Vehicle Control

IAG&C

Middleware Operating System

Hardware Platform

### IMS

Common Simulation Infrastructure

Observe Event Handler

Configuration Control

Orient & Decide Capability Reasoner

Middleware Operating System

Hardware Platform

Data Store

Sim Interface

Sim Interface

### Flight Control Actuation

Sim Interface

### Vehicle Parameters

*TPS Model*

Number of tiles	1444
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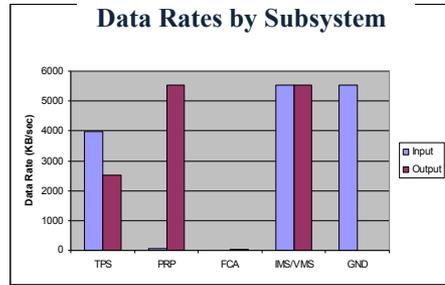
*TPS Tile*

Sensor Type	ImpactPZT	Temperature
Number of sensors	0.45	0.25
On command only (y or n)	y	y

*DACHM*

Processor Type	
Number of processors	

Configuration Data



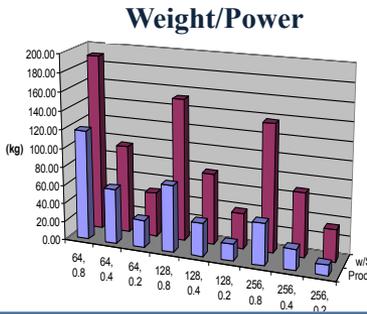
## Sim Interface

### ISHM Sim Executive

Quantification    ICD Validation    Optimization

Health Status & Alerts to VMS & OCC

CBM => Rapid Turnaround





# ISHM Architecture Quantification



Weight: 161.4 lbs

Power: 493 W

3 Engine  
DACHMs

4 TPS  
DACHMs  
WLE & TA

1 Avionics  
DACHM

## Max Data Rates

- TPS DACHM - In: 7923 KB/s, Out: 2516 KB/s
- Engine DACHM - In: 49 KB/s, Out: 5520 KB/s
- IMS - 5528 KB/s (8 combined sources)

## Max Total Data

- Propulsion DACHM: 385 MB
- TPS DACHM: .02 MB
- IMS: 18 MB

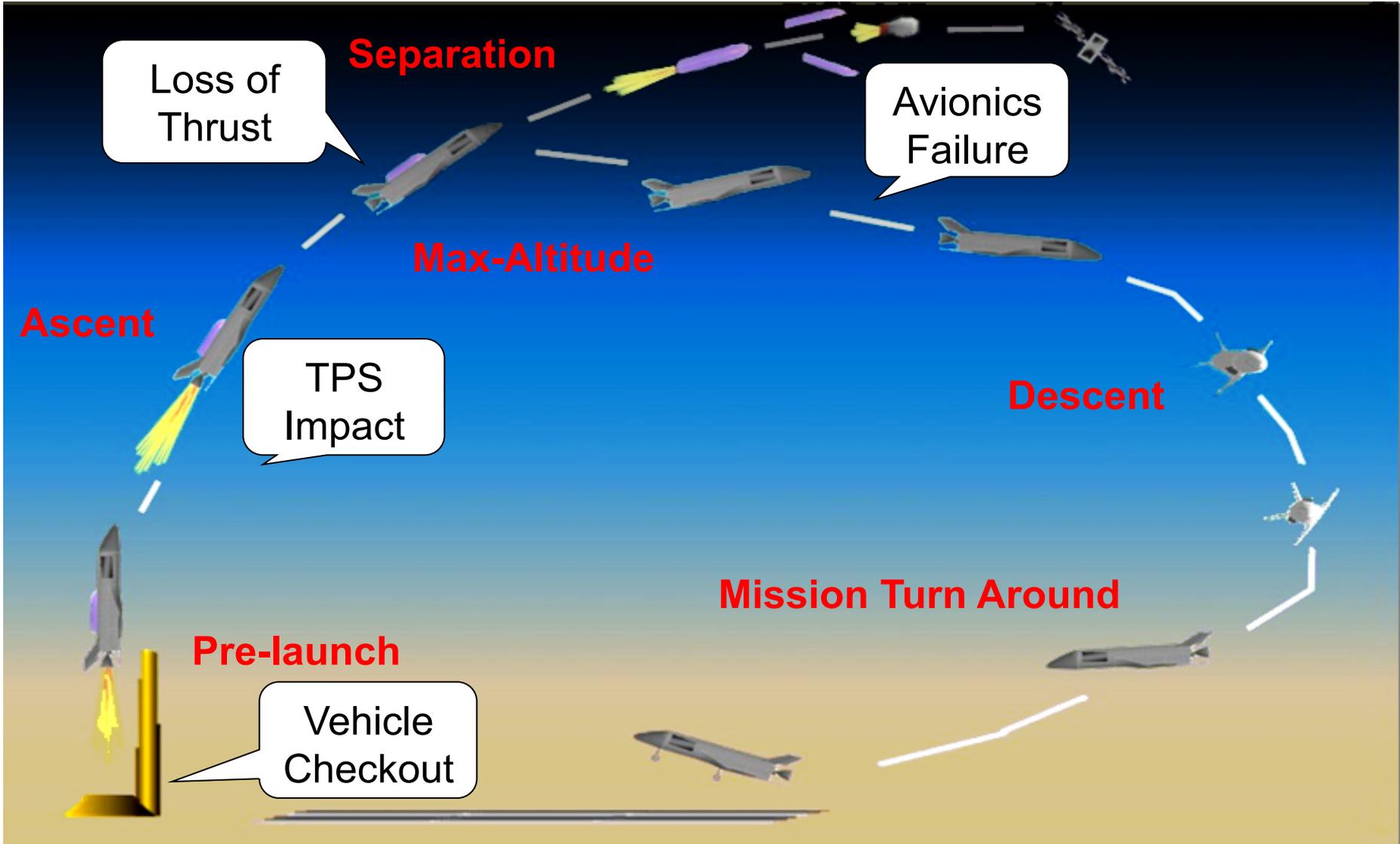
Data Compression DACHM to IMS: 21 to 1

## DACHMs: 8 units

- 4 TPS - 256 I/O channels, assumes 1 sensors per 5 square ft
- 3 engines: 64 I/O channels, 47 standard sensors each
- 1 Avionics: monitors IMA virtual bus



# Baseline Vehicle Concepts of Operations

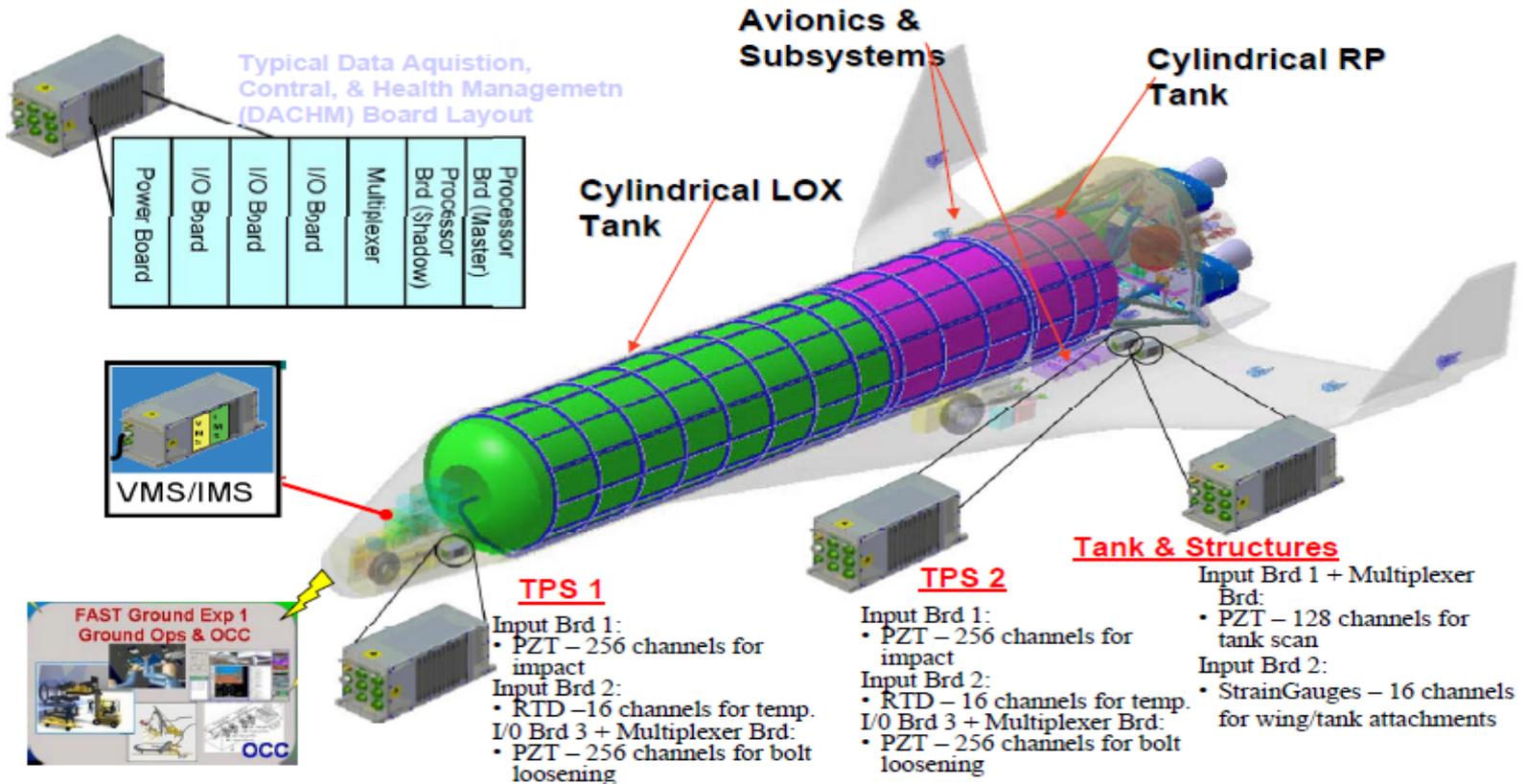




# FAST ISHM Architecture Design



## ISHM Architecture for FAST RFS

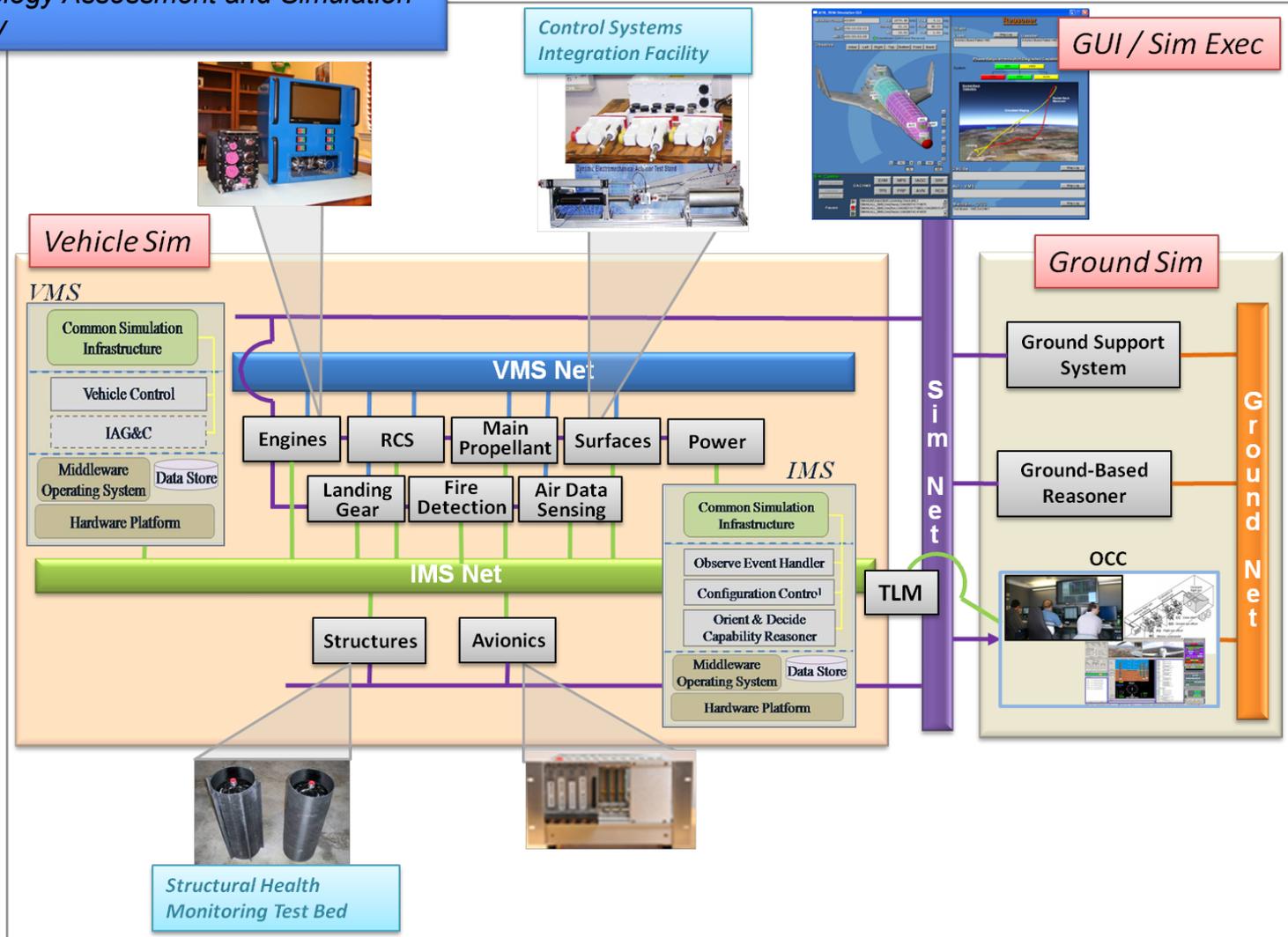




# ISHM Laboratory

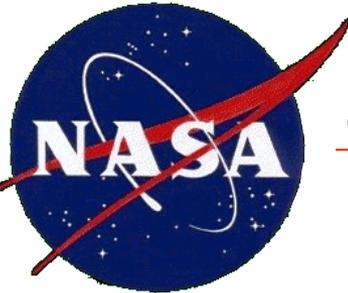


Air Vehicles Technology Assessment and Simulation (AVTAS) Laboratory



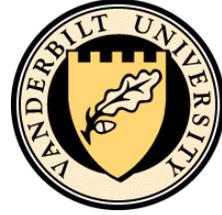


# Research Team & Resources



*JFA Avionics Systems, Inc*

LOCKHEED MARTIN



FLORIDA INTERNATIONAL UNIVERSITY





# The ISHM Goal



**“I don't care about what anything was DESIGNED to do,  
I care about what it CAN do”.**