Integrated Vehicle Health Management (IVHM) for NASA's proposed Orbital Space Plane (OSP)

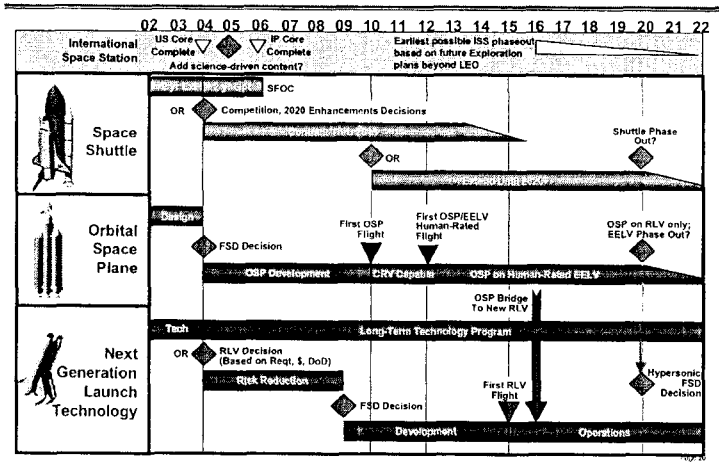
Ed. Baroth, Ph.D
OSP IVHM Deputy Lead
Sensor Oversight POC

Jet Propulsion Laboratory
California Institute of Technology
ebaroth@jpl.nasa.gov

Networks, Sensors, and Computing Panel Discussion

- Our Organization
  - NASA
- Our Success (Pick any three)
  - More missions
  - Safer missions
  - Cheaper missions (which leads to more missions but are they safer?)
- What technologies can help NASA achieve success?
  - IVHM, among others
- What is an important component of IVHM?
  - Embedded computer networks, among others
- Therefore, what is the impact of EmNets on future success?
  - Crucial (but I may not be impartial)

ISTP Roadmap

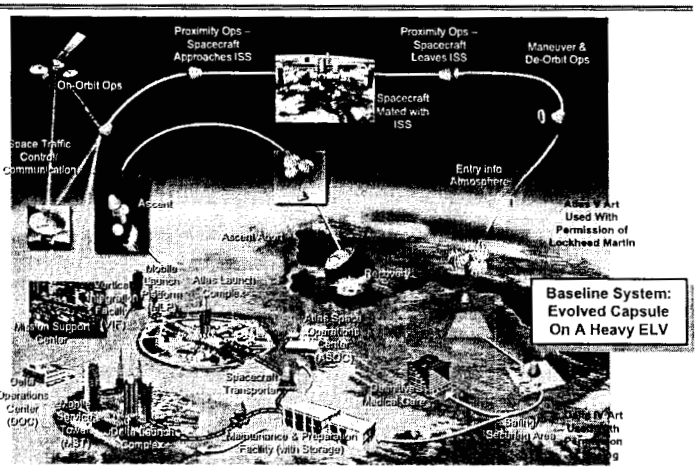


OSP Background

- What is the OSP?
  - 4 person crew rescue vehicle from the ISS
  - Launched autonomously on an expendable in '08
  - Crew transfer vehicle to/from the ISS by '12
- Where is it managed?
  - Code R Project, part of ISTP (Integrated Space Transportation Program)
  - Managed out of MSFC
  - Headed by Dennis Smith and Dan Dumbacher
- Major industry players - vehicle architecture contracts issued in 2000 - Current contracts extended with Mod 1 until March '04
  - Boeing
  - Lockheed Martin*
  - Northrop Grumman* / Orbital

* Now teamed

Baseline OSP System



Page 5

Health Management

The Safety and Affordability of All Launch Systems Are Driven By Things That Were Not Supposed to Happen, i.e., Failures of the System

There Are Fundamentally Two Approaches to Dealing With Failures:

1. Design Failures Out of the System
2. Manage the Failures That Remain

Health Management
Improves Safety and Affordability
by Helping to Intelligently Manage Failures
That Cannot Be Designed Out

Page 6

Challenge to Previous Slide

At the design phase:

The Beautiful Baby Syndrome applies (with apologies to Steve Brown at NGC)

- My subsystem will have no faults to manage
- My subsystem will not fail
- How dare you imply that my subsystem will have any failure modes

- Therefore - Health Management is not needed

But Later ...

During Full Scale Development:

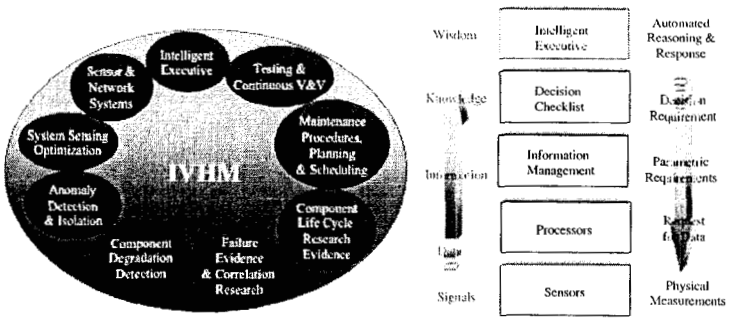
- When the system has been designed
- When failure modes are identified
- When Health Management is seen to be needed

- It may be too late to 'add' it to a designed system

- Therefore, if must be part of the design process

IVHM is fundamentally Data Acquisition & Analysis

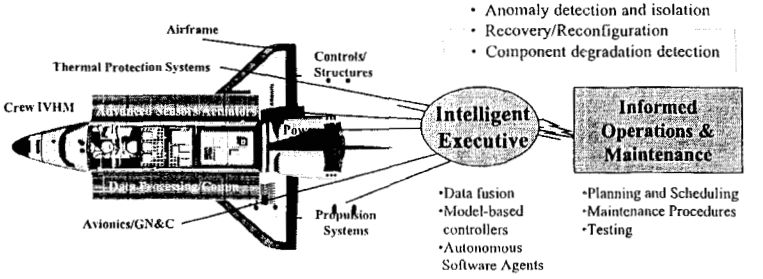
- IVHM (as an integrated technology) uses many different types of data to support decision making



Integrated Vehicle Health Management

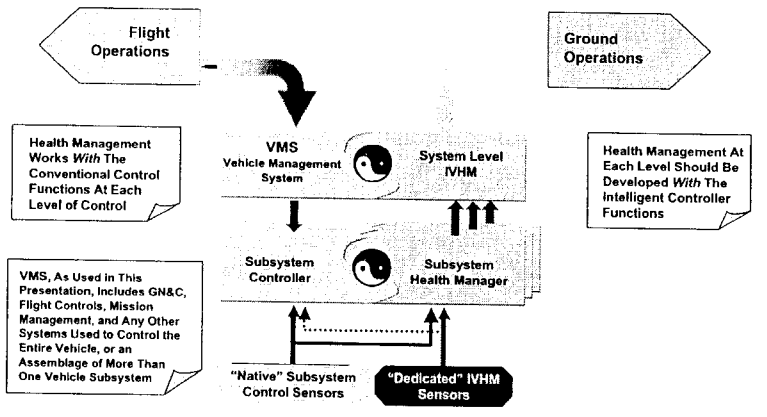
Collect, process, and integrate information about the health of a launch system including the vehicle, subsystems, components, sensors, and ground support systems to make informed decisions and take appropriate actions to ensure the success of a mission

- Anomaly detection and isolation
- Recovery/Reconfiguration
- Component degradation detection



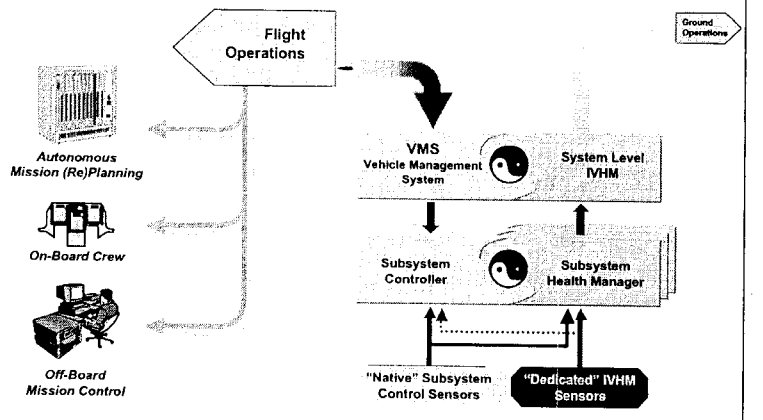
The Union of Advanced Hardware and Software -
Providing higher reliability & safety, with greater robustness, at lower costs

IVHM Enables Informed Control



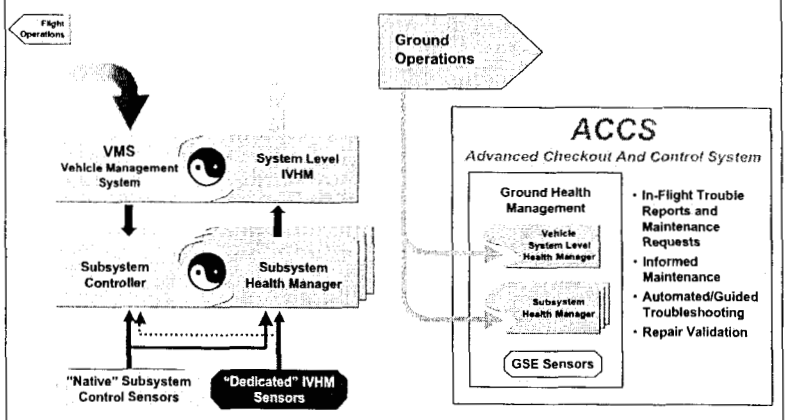
Page 11

IVHM Enables Informed Flight Operations



Page 12

JPL IVHM Enables Informed Ground Operations



JPL Systemic Health Management Trades

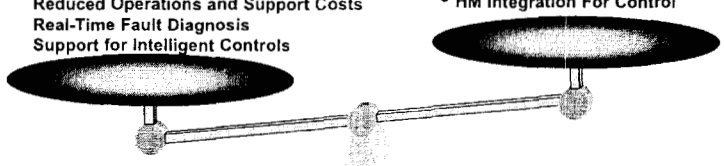
System
- Improved Safety
- Reduced Operations and Support Costs
- Comprehensive Knowledge of the Current Vehicle State
- Support for Informed Autonomous Decision Making

Subsystem
- Improved Safety
- Reduced Operations and Support Costs
- Real-Time Fault Diagnosis
- Support for Intelligent Controls

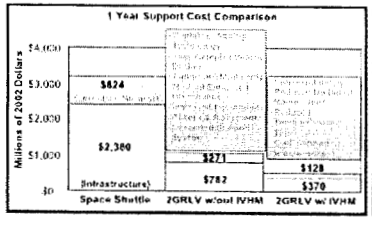
Costs

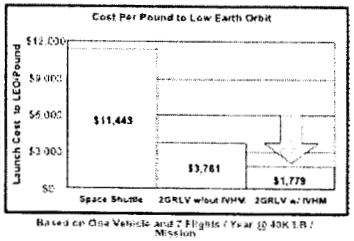
System
- Increased Software/Processing
- Increased Communications
- HM Integration For Control
- Telemetry/Storage Bandwidth

Subsystem
- Dedicated Sensors (If Any)
- Increased Software/Processing
- Increased Communications
- HM Integration For Control



IVHM Operations & Support Cost Avoidance





Based on One Vehicle and 7 Flights / Year @ 40K LB / Mission

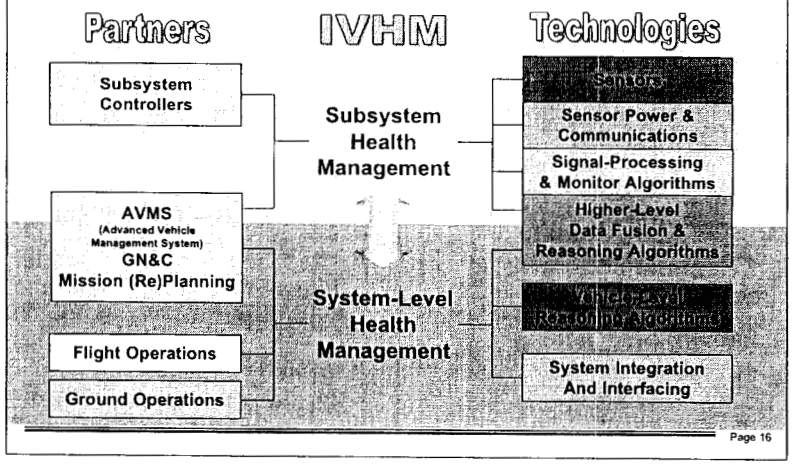
30 Year Operational Service Life

- Based on Detailed O&S Cost Modeling Using NGC VFB-2 2GRLV Architecture
- Analysis Available On Request

$4.3B 30 Yr Savings — Recurring

$610M Investment — Non-Recurring

= **7.0** Benefit to Cost Ratio

52% Reduction in Support Costs

IVHM Flight Technologies