IVHM for the 3rd Generation RLV Program – Technology Development

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Integrated Vehicle Health Management
♦ Project Objectives:
Develop and integrate the technologies which can provide a continuous, intelligent, and adaptive health state of a vehicle and use this information to improve safety and reduce costs of operations.

♦ Technology Objectives:

• Develop, validate, and transfer next generation IVHM technologies to near term industry and government reusable launch systems.

• Focus NASA on the next generation and highly advanced sensor and software technologies

• Validate IVHM systems engineering design process for future programs
Global Civil Aviation

Reduce Accident Rates, 10x

Reduce Trans-oceanic Travel time by 50%

Reduce Launch Cost to LEO, 100x by 2020

Reduce Emissions, 5x

Reduce Noise, 4x

Revolutionary Technology Leaps

Increase System Throughput, 3x

Invigorate GA 20K units Annually

Cut Development Cycle Time in Half

Access to Space

Reduce Cost of Air Travel by 50%

IVHM Objectives

• Safety
• Reliability
• Mission Assurance
• Reduced Maintenance Costs
• Efficient Vehicle Turn-Around

IVHM Methodologies

• Sensor Technology
• Information Technology
• Communication Technology

Integrated Vehicle Health Management

IVHM Support of NASA Pillars and Goals
SpaceLiner Technology Ratings Reported Through ISTP

- Safe structures design technologies
- Advanced mat, fab, mfg and asbly
- Aero/Aerothermody tools rapid det
- Integrated design environment
- RLV crew interface technology
- Nonlinear airframe dynamics
- Cryotank structures
- Structurally integrated avionics
- Hot and cooled airframe structures
- Aerodynamic perf & cntl via morph
- Airframe design and databasing
- Avionics IVHM
- Power IVHM
- Ground segment IVHM
- SE&I IVHM
- Structure IVHM
- Propulsion IVHM
- Advanced checkout and control
- Intelligent instrumentation and inspe
- On-site demand
- Umbilicals
- Payload systems technology
- Integrated storage and recovery
- Zero-loss transfer
- MagLev development
- HC TSTO RBCC Airbreather
- NPSS for space trans prop (ISE,IAEE
- H2 SSTO RBCC Airbreather
- Long life high T/W HC ROCKET
- Long life light weight prop mat & str
- Information rich test instrumentation
- PDEBCC Rocket
- TSTO TBCC airbreather
- PDEBCC Airbreather
- SSTO TBCC airbreather
- High performance hydrocarbon
- Long life high T/W H2 ROCKET
- Propulsion life prediction
- High (better than densified) density
- Green mono prop RCS
- Integrated propulsion mgt system
- Decision support models
- Weather instrumentation systems
- Space based range
- Spaceport range systems
- Sharp Body TPS demo (Sharp L1)
- Develop adaptive intelligent/ IVHM s
- Quick change-out TPS
- Highly reusable TPS
- Quick TPS inspection
- ISE tool development for TPS life cy

3rd Generation RLV Technology Ratings

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, with greater robustness, at lower costs

Integrated Vehicle Health Management

IVHM
### Major Milestones & Decisions

<table>
<thead>
<tr>
<th>Year</th>
<th>Milestone</th>
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<tbody>
<tr>
<td>FY00</td>
<td>X-34 Flights</td>
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<tr>
<td>FY01</td>
<td>X-33 Flights</td>
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<tr>
<td>FY02</td>
<td>X-37 Flights</td>
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<tr>
<td>FY03</td>
<td>Concept Downselect</td>
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<td>FY04</td>
<td>Ops Demo</td>
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<tr>
<td>FY05</td>
<td>Competition</td>
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<tr>
<td>FY06</td>
<td>Advanced Tech.</td>
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<tr>
<td>FY07</td>
<td>Focused Tech.</td>
</tr>
<tr>
<td>FY08</td>
<td>Advanced Dev</td>
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<tr>
<td>FY09</td>
<td>Flight Demo</td>
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<tr>
<td>FY10</td>
<td>Foundation Technology</td>
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<td>3rd Gen Unique</td>
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### Key Tasks
- Distributed Avionics IVHM Architectures
- Intelligent Propulsion & Power Mgmt/Dist. IVHM
- Smart Thermal Protection and Auto Inspector
- On-Board Structure Fiber Optic and Acoustics
- Informed Ground Operations - Launch/Mission
- Virtual IVHM Simulator ---- HW/SW Testbed
- IVHM National Testbed

### SSME Health Management
- Propulsion exp.
- X-34 Flights
- IVHM Software Experiment
- X-37 Flights
- Wireless/Nano Instrumentation, Automated Vehicle Sensed Inspection Systems, Self-Healing IVHM

### Future Flight Experiments and Demonstrations
- Advanced Sensors From Discipline Programs
- Integrated/Subsystem Demo

#### IVHM Level II Roadmap

**Integrated Vehicle Health Management**
### Major Milestones

- **Commit to Flight Configuration Decisions**

### Key Tasks

- **Component/Subsystem Demo**
- **Integrated Demo**
- **Flight Demo**
- **Foundation Technologies**
- **Companion System Definition**

### Structures IVHM: Tunable Laser Source and Fiber Optic Component

<table>
<thead>
<tr>
<th>Year</th>
<th>Task</th>
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<tbody>
<tr>
<td>2000</td>
<td>Design Hdbk</td>
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<tr>
<td>2001</td>
<td>Cost/Benefit Simulations</td>
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<tr>
<td>2002</td>
<td>Informed Maintenance Demos</td>
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### Propulsion IVHM: Ground Demonstration of RLV IVHM Components and Systems

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<tbody>
<tr>
<td>2000</td>
<td>HGDS Review</td>
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<tr>
<td>2001</td>
<td>PMAD IVHM Prototype</td>
</tr>
<tr>
<td>2002</td>
<td>Wireless Structure IVHM Concept</td>
</tr>
<tr>
<td>2003</td>
<td>Wireless Propulsion IVHM Concept</td>
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### Power IVHM: Algorithms and Diagnostics for Power Management and Distribution

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<tr>
<td>2000</td>
<td>PMAD IVHM Prototype</td>
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<td>2001</td>
<td>AITPS Ground Tests</td>
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### Avionics IVHM: Prototype IVHM Software On Smart Wireless Networks

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<td>Smart Sensor Networks</td>
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### Ground IVHM: Vehicle Servicing, Check Out, and Informed Maintenance

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### IVHM SE&I

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### Virtual IVHM Testbed and Integrated Subsystem Demonstrations

### Integrated Vehicle Health Management

**IVHM Roadmap**
Advice
• Scope - Develop a university and university sponsored research institute team to act as a peer review for project and program strategies and tactical planning
• Initial discussions held with a few universities. Others to follow.
• Continue to leverage activities of the IVHM National Team to survey and gain access to the best ideas from universities.

Collaboration
• Scope - Universities identified as contributors in IVHM Projects:
  – Smart, Self Healing Sensory Systems
  – Self Learning, Self Correcting Propulsion Systems
  – Structures IVHM

The project office is seeking new partnerships with the academic community.
Integrated Vehicle Health Management

ARC Is Coordinating IVHM For Space Transportation