Integrated Vehicle Health Management for the 2nd Generation RLV Program

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- 2nd Generation RLV Program
- 3rd Generation RLV Program
- The NASA X-37 IVHM Flight Experiment
- Propulsion and Power IVHM
- Integrated Vehicle Health Management (IVHM) Activity at Kennedy Space Center
- IVHM Technology at JPL
- Structures IVHM for 3rd Generation RLVs
- IVHM Systems Engineering and Integration

Session Overview

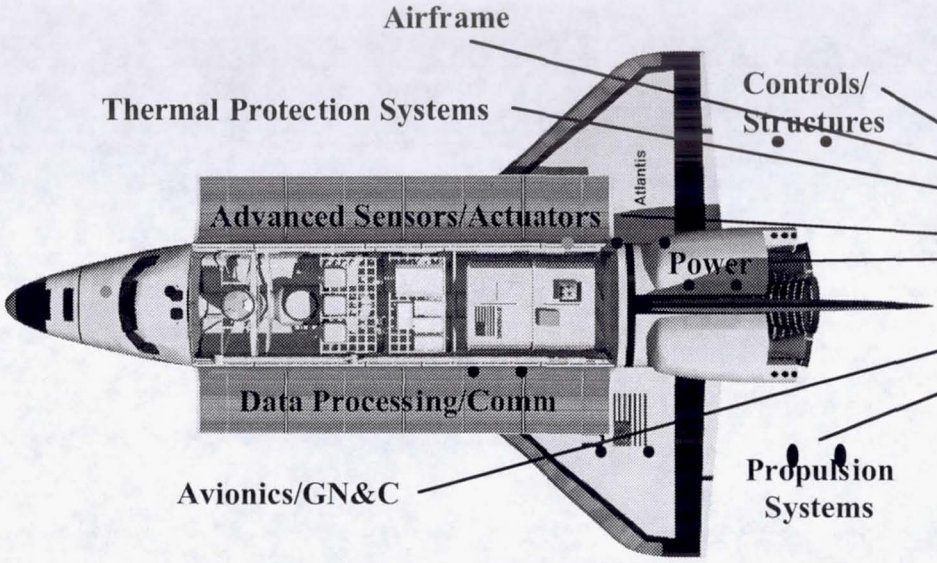
Space Launch Initiative Goals

- Commercial Convergence – Flying on Privately Owned and Operated Launch Vehicles
- Competition - bringing innovation and new ideas to bear
- Assured Access – ensuring alternate means of getting to space despite launch mishaps
- The Ability to Evolve – adding new capabilities affordably as new mission needs emerge

2nd Generation RLV Program Goals

- Safety – Fewer than 1 loss of crew incident every 10,000 flights
- Reliability – Fewer than 1 loss of vehicle every 1,000 flights
- Cost – Less than $1000/lb payload cost to low earth orbit

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

Intelligent Executive

- Data fusion
- Model-based controllers
- Autonomous Software Agents

Informed Operations & Maintenance

- Planning and Scheduling
- Maintenance Procedures
- Testing

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

Integrated Vehicle Health Management
IVHM

Propulsion/Engine/OMS

- **Automated Data Analysis**
- **Condition based maintenance**
- **Advanced Real-time Anomaly Detection**
- **Advanced Instrumentation -MEMS, Hi temp, plum spec, high freq**
- **On-Board Automated Leak detection**

Thermal Protection

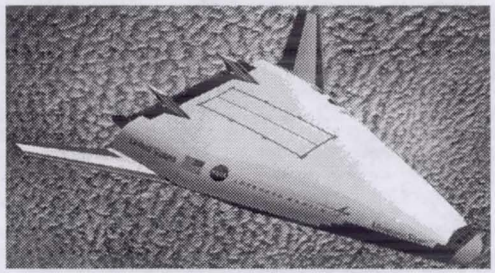
- **MEMs Temp/Pressure Sensors for Overgap Filling**
- **Real-Time Smart TPS Diagnostic SW**

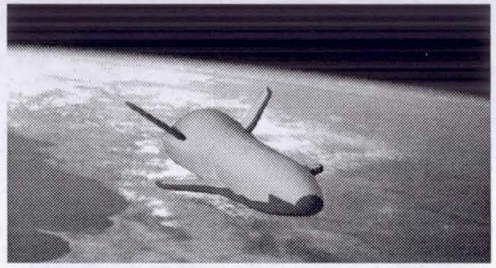
Airframe Structure

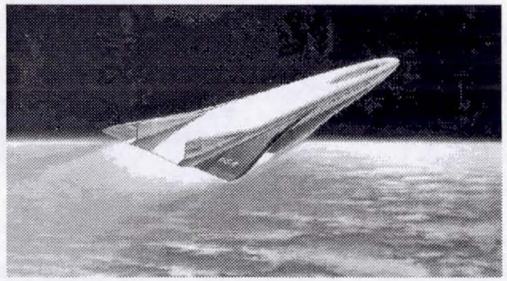
- **Flight Fiber Optic (FO) Tunable Lasers**
- **Real-time Dynamic FO Measurements**
- **Acoustic Emission/Acoustic Ultrasound**
- **Advanced low/high temp sensitivity**

Crew System

- **Crew Monitoring/Diagnostic Systems**
- **Human-centered computing (HCC) Crew Smart Sensor Algorithms**







Avionics

- **Non-intrusive high response measurements of Pressure, Temp, Strain, Acceleration**
- **Fiber Optic Network Management SW**
- **Wireless High Speed Data Mgmt**
- **Multi-tasked/cause-effect data mining**
- **Multi-use Smart Sensor Algorithms**
- **Distributed decision-making software**
- **Vehicle and Subsystem MBR Tech**
- **Automated feature recognition**
- **Real-time fault prediction software**
- **Reprogrammable/Reconfigurable FDIR**
- **Automated software V&V technologies.**
- **Auto mission planners/schedulers**

Ground System

- **Advanced Launch/Mission Diagnostics/Prog**
- **Automated ground-based maintenance planners/schedulers/work order generator**
- **Facility Automated Leak detection Hand-Held Portable Maintenance Aid HW**
- **Automated TPS/Airframe NDE/NDI**

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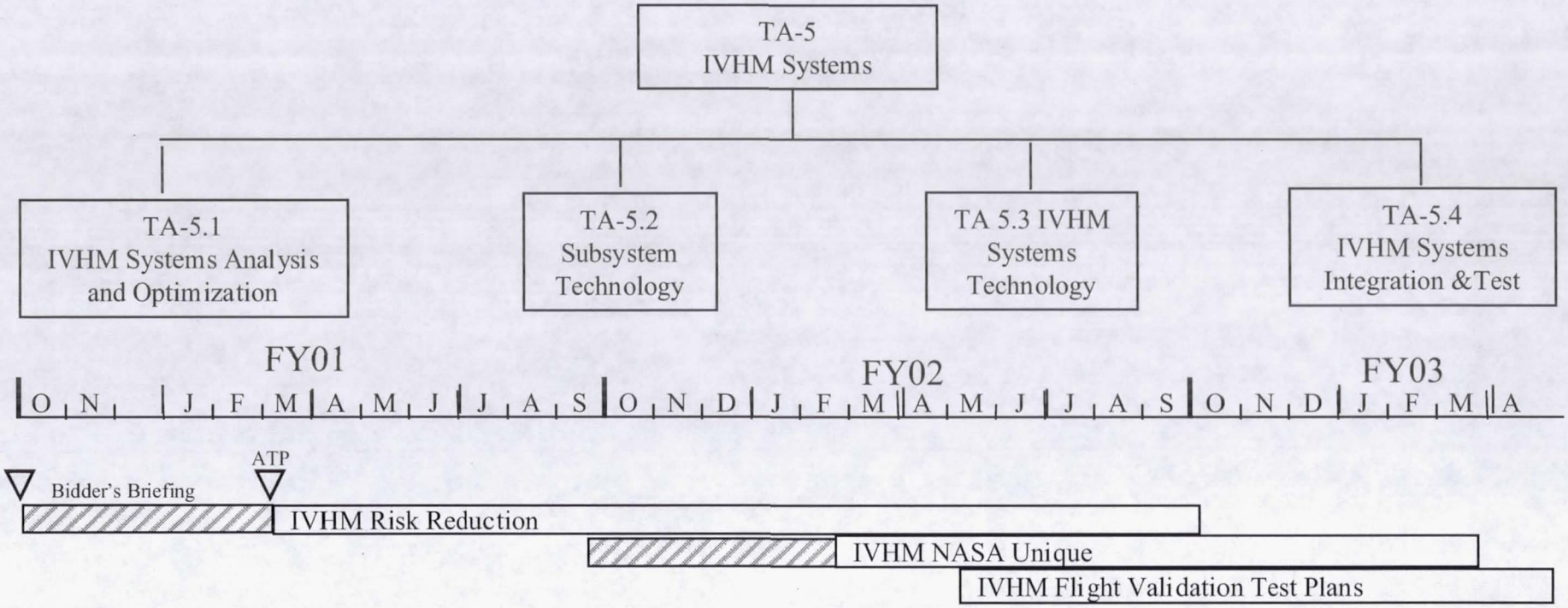
Some IVHM Technologies



Milestones

Industry Lead Tasks	Commercial Req'ts Baselined	IVHM Systems Integration Plan	IVHM System Simulations Initiated		HWIL/SWIL Bench Top Testing Initiated	HWIL/SWIL Subsystem Testing Initiated
	Verification Data Defined	Ground Test Plan Defined	Flight Exp'ts Defined	Qualification Data and out-year Plans	IVHM System Sims Downselected	Qualification Data and Metric Evaluation

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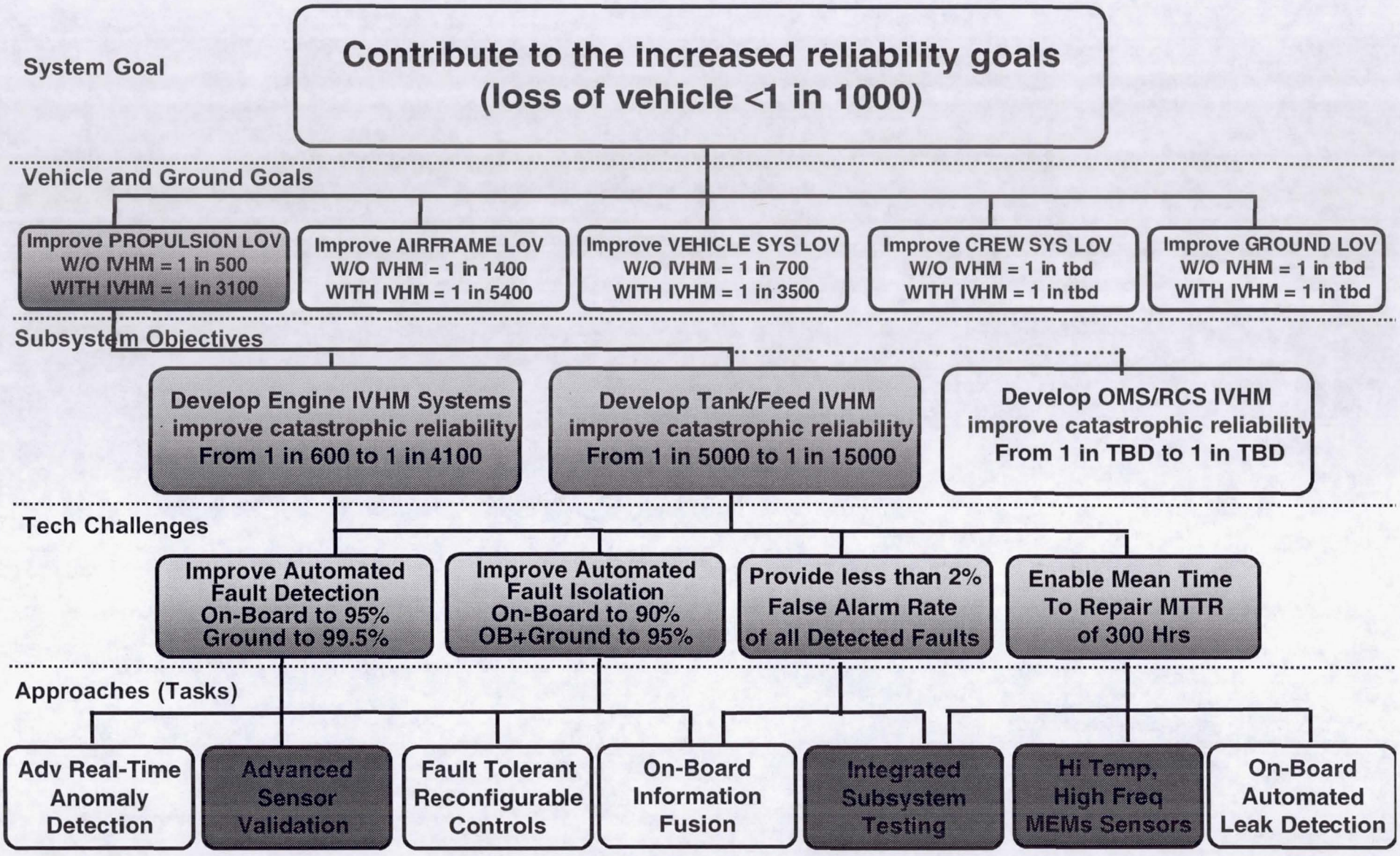
Roadmap



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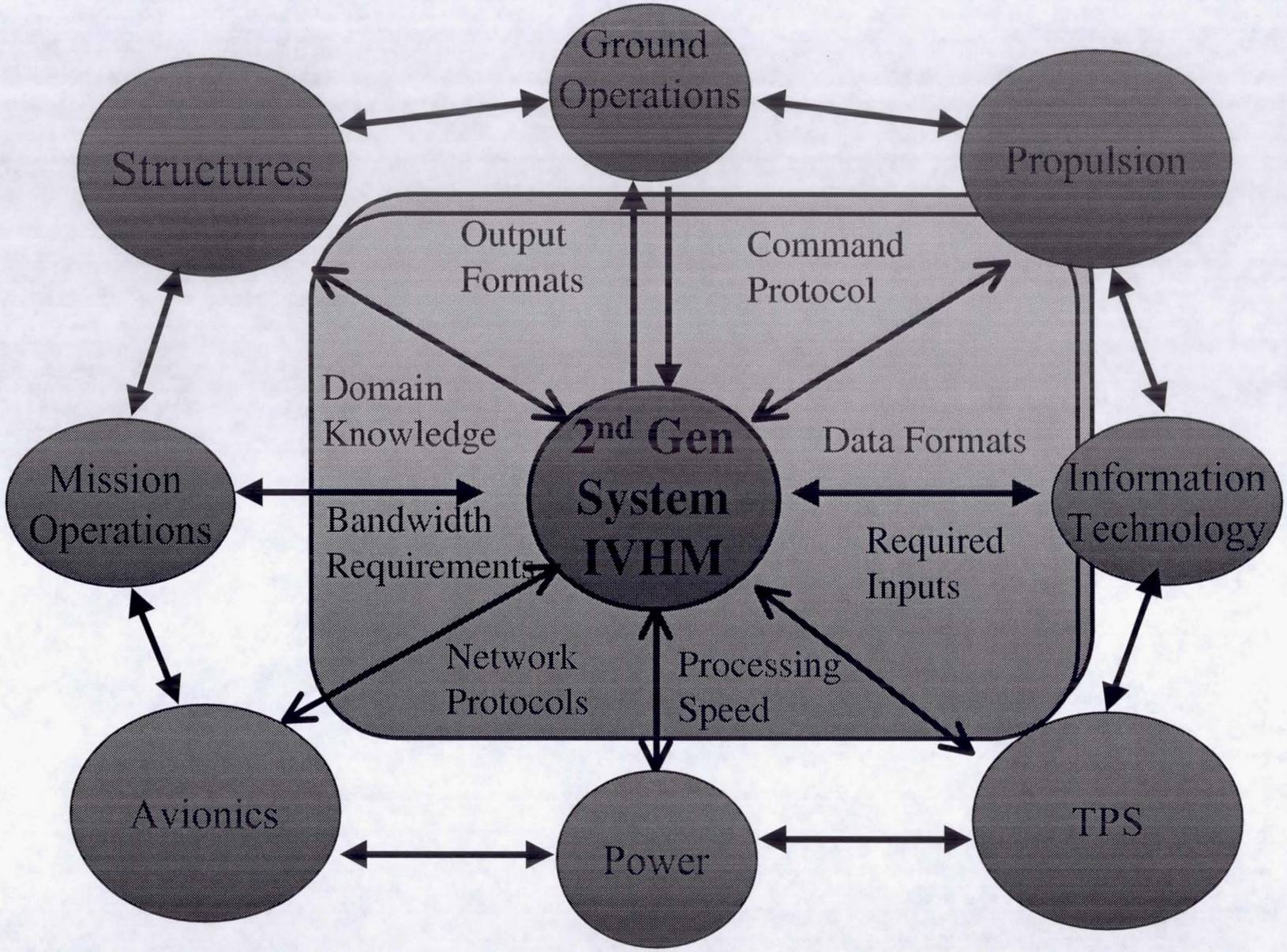
Requirements Flowdown (TA-5.1)



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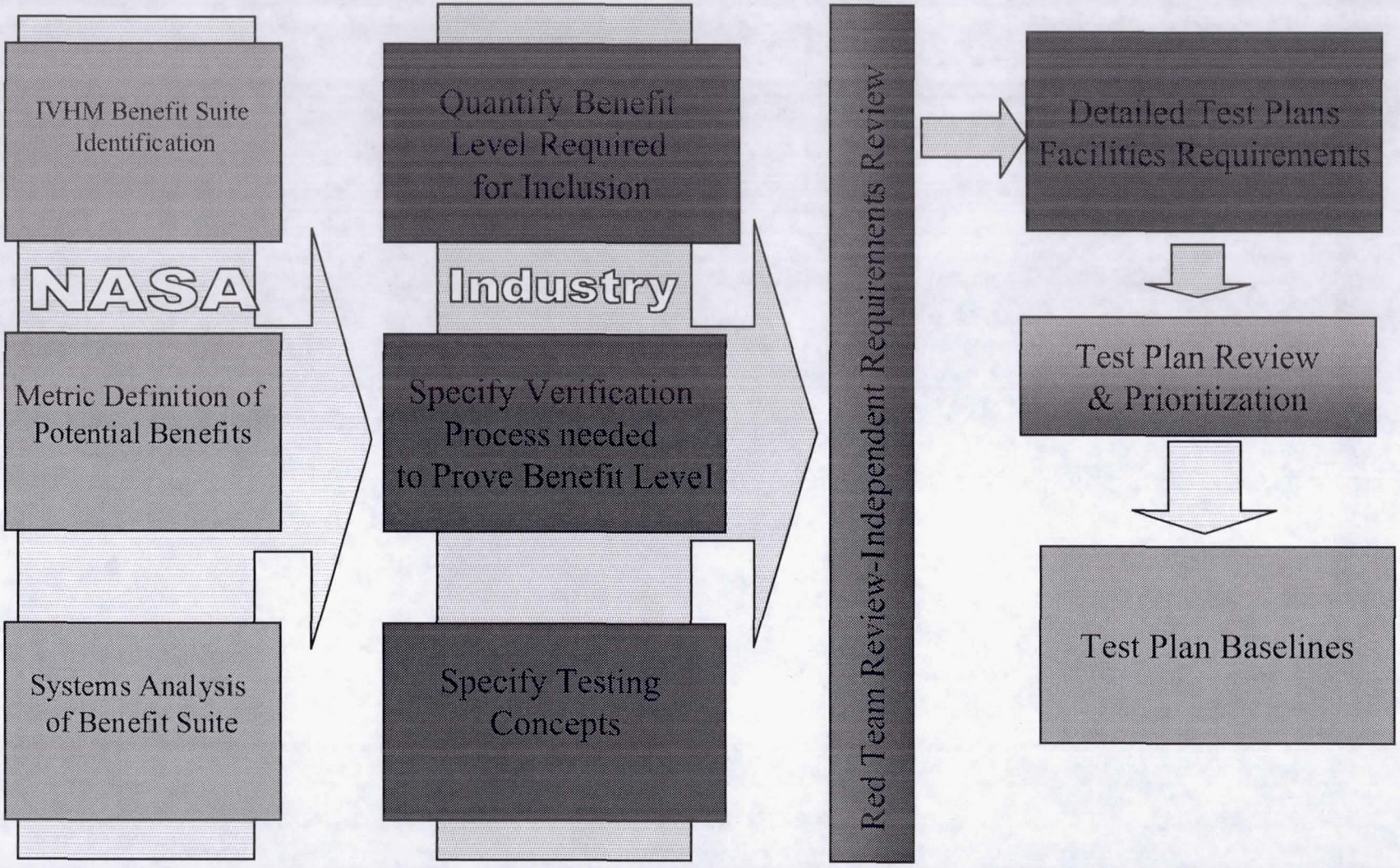
Interface Definitions TA-5.2

- The introduction of IVHM will dramatically increase the amount of software required. Overall viability of IVHM may hinge on developing the ability to write and flight certify this software more cheaply than present practice, but with no compromise on safety. How can we do this?
  - Formal Methods- Provable adherence to standards and requirements
  - Agency Best Practices – Example: Shuttle software team
  - Software Health Monitoring – On board monitoring of software state. Internal consistency checks against test data. Redlines.
  - Automated verification strategies. Use of Cardinality.
  - Fault Tolerant software.
  - Automated software generation environments



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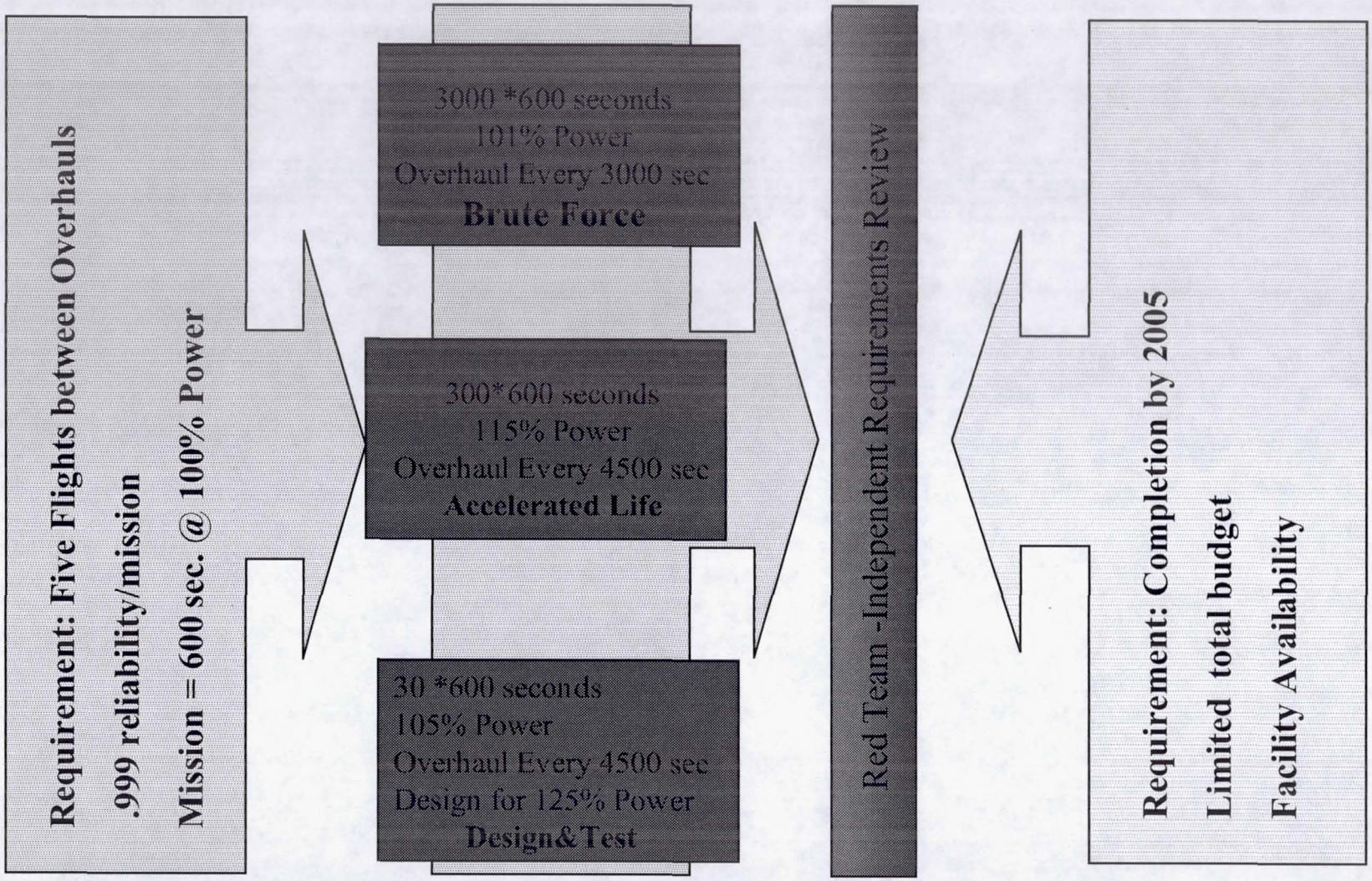
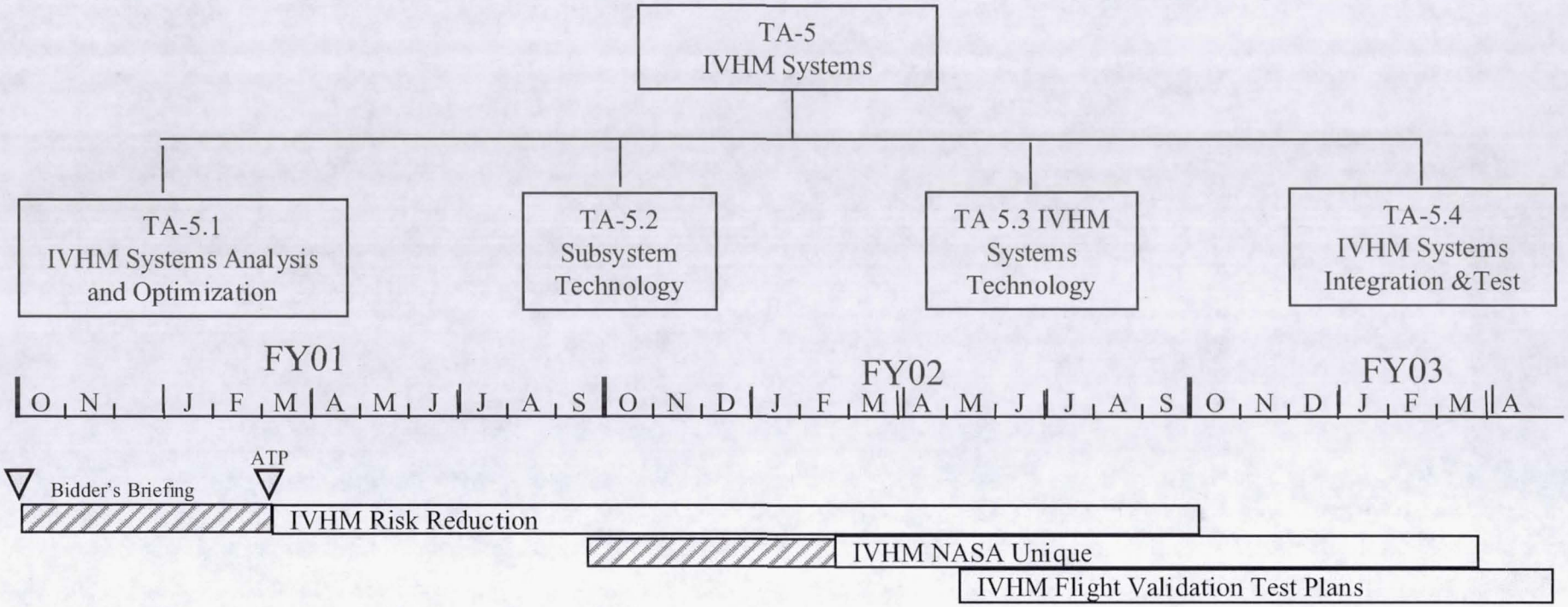
Requirements Definition (TA-5.4)



Requirements Verification & Testing (TA-5.4)



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Roadmap

Technical Area	Name	Phone
2nd Gen Manager	Bill Kahle	256-544-3225
Propulsion	Jim Snoddy June Zakrajsek	256 544-4972 216-977-7470
TPS	Carol Carroll	650-604-0267
Systems Engineering	Kevin Flynn Dave Squires	650-604-4062 650-604-0072
Avionics	Anthony Kelly	256-544-7646
Launch Operations Mission Operations	Jack Fox Ron Cobbs	321-867-4413 281-483-5894
Vehicle Power	June Zakrajsek	216-977-7470
Structures	Bob Rogowski	757 864-4990
System IVHM	Tom Gormley	650-604-1831
Flight Planning	Keith Schweikhard	661-276-3411

IVHM Interfaces