NASA Space Technology Draft Roadmap Area 13: Ground & Launch Systems Processing

Greg Clements, presenter

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Space Technology Roadmaps Process

NASA Process

8: DRAFT NASA STRs
OCT released draft Space Technology Roadmaps to the NRC & to the Public

7: Internal Reviews
Each TA Roadmap reviewed by OCT & extended teams of subject experts

6: Roadmapping Process
Preliminary roadmaps for TA areas

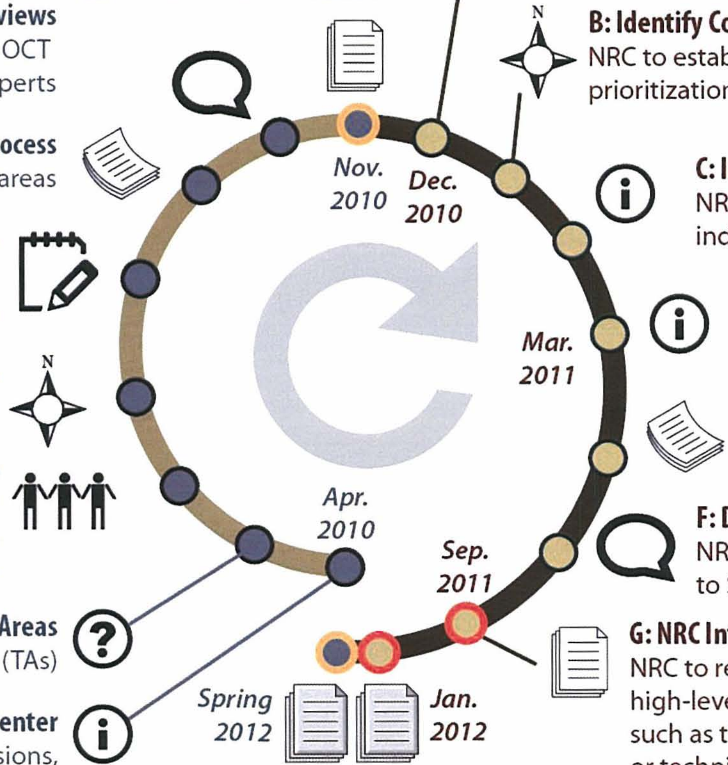
5: Form Starting Point for TA Roadmaps
Assessed past roadmaps; MD & Center inputs

4: Common Approach for TA Teams
Guidelines, assumptions, deliverables

3: Establish TA Teams
OCT established NASA internal 6-member subject expert teams for each TA, with one or two chairs

2: Identify Technology Areas
Identified Technology Areas (TAs)

1: START & Input from MDs & Center
Identified MD Goals, Missions, Architectures & Timelines; MD Technology Roadmaps & Prioritizations; Center Technology Focus Areas



9: FINAL NASA STR REPORT
NASA to release Roadmap Report

NRC Process

A: Establish NRC Teams
NRC to appoint steering committee and 6 panels

B: Identify Common Assessment Approach
NRC to establish a set of criteria to enable prioritization within and among all TAs

C: Initial Community Feedback
NRC to solicit external input from industry & academia

D: Additional Community Feedback
NRC to conduct public workshops

E: Deliberations by NRC Panels
NRC panels meet individually to prioritize technologies and suggest improvements to roadmaps

F: Documentation by NRC Panels
NRC Panels to provide written summary to Steering Committee

G: NRC Interim Findings
NRC to release a brief interim report that addresses high-level issues associated with the roadmaps, such as the advisability of modifying the number or technical focus of the draft NASA roadmaps

H: FINAL NRC REPORT
With decisional information, including: summary of findings and recommendations for each of the roadmaps; integrated outputs from the workshops and panels ; identify key common threads and issues; priorities, by group (e.g., high, medium, low), of the highest priority technologies from the TAs

NASA Space Technology Roadmaps Process

Technology Area Overview

The Scope of TA #13 includes:

- Assembly, integration, and processing of the launch vehicle, spacecraft, and payload hardware
- Supply chain management
- Transportation of hardware to the launch site
- Transportation to and operations at the launch pad
- Launch processing infrastructure and its ability to support future operations
- Range, personnel, and facility safety capabilities
- Launch and landing weather

Technology Area Overview

The Scope of TA #13 also includes:

- Environmental impact mitigations for ground and launch operations
- Launch control center operations and infrastructure
- Mission integration and planning
- Mission training for both ground and flight crew personnel
- Mission control center operations and infrastructure
- Telemetry and command processing and archiving
- Recovery operations for flight crews, flight hardware, and returned samples

Technology Area Overview

- **HIGH RECURRING COSTS**. . . are the bane of our nation's Space Program. . .and significantly and negatively impact our ability to fulfill NASA's mission

Technology Area Overview

- What are the challenges and cost drivers in our current Ground and Mission operations?
  - Dated, Vehicle-unique infrastructure
  - Labor intensive operations
  - Proliferation of duplicative systems
  - Lack of sufficient insight into system configuration/ system performance margins
  - Low mission availability due to weather restrictions and significant maintenance/ refurbishment required between missions
  - Conservative risk and safety postures

Technology Area Overview

- TA #13 identifies ground, launch and mission technologies that will:
  - Dramatically transform future space operations, with significant improvement in life-cycle costs
  - Improve the quality of life on earth, while exploring in co-existence with the environment
  - Increase reliability and mission availability using low/zero maintenance materials and systems, comprehensive capabilities to ascertain and forecast system health/configuration, data integration, and the use of advanced/expert software systems
  - Enhance methods to assess safety and mission risk posture, which would allow for timely and better decision making

Technology Area Breakdown Structure

Ground and Launch Systems Processing

Goal: Flexible/Agile U.S. Ground and Mission Launch, Operations, and Recovery Capabilities to significantly increase access to space by reducing life cycle costs, reducing environmental impacts, increase mission availability and improve mission risk and safety posture

13.1 Technologies to Optimize the Operational Life-Cycle

13.1.1 Storage, Distribution and Conservation of Fluids

1. High efficiency/zero loss storage
2. High efficiency fluid transfer
3. High efficiency recovery, purification, and reliquefaction systems
4. Limited resource conservation (e.g., Helium)
5. Fluids system components
6. Low-cost commodity production
7. Fluid servicing

13.1.2 Automated Alignment, Coupling, and Assembly Systems

1. Positioning and alignment systems
2. Automated control systems (self positioning, self-configuring)
3. Automated ground-to-vehicle and ground–to-payload umbilicals and interfaces
4. Leak free quick disconnects with self sealing capability
5. Latching, actuation, mating and release mechanisms (shape memory alloys)
6. Automated handling and assembly (robotics)

13.1.3 Autonomous Command and Control for Ground Systems and Integrated Vehicle/Ground System

1. Next-generation modeling capabilities for life-cycle
2. Mission preparedness technologies
3. Computing
4. Open, ground system service-oriented architecture (common multi-mission infrastructure)
5. Automated planning and scheduling tools
6. Automated/autonomous information systems
7. Transferring mission operations ground planning and scheduling software to the flight element

13.2 Environmental and Green Technologies

13.2.1 Corrosion Prevention, Detection and Mitigation

1. Prevention: environmentally friendly corrosion resistant materials and systems
2. Detection of hidden corrosion (i.e. under paint)
3. Control and mitigation

13.2.2 Environmental Remediation and Site Restoration

1. Groundwater and soil contamination detection and mitigation (pollution/contaminant removal)
2. Airborne release detection and mitigation (emission control)
3. Spill/damage prevention and response technologies
4. Environmentally friendly remediation of waste and materials

13.2.3 Preservation of Natural Ecosystems

1. Carbon sequestration technologies
2. Reduction of nutrient runoff into Estuaries and Waterways (bio-reactors for wastewater treatment)
3. Nitrocision for coating removal - eliminates contaminated sand blast media and water
4. Laser based surface prep technologies - to replace chemicals used to etch/activate substrate surfaces reducing hazardous streams

13.2.4 Alternate Energy Prototypes

1. Alternative fuels (non-toxic propellants)
2. Green products, materials, and processes
3. Alternate energy sources

13.3 Technologies to Increase Reliability and Mission Availability

13.3.1 Advanced Launch Technologies

1. Multi-vehicle launch capabilities (e.g. universal launch pad)
2. Vertical launch capabilities
3. Horizontal launch capabilities
4. Air launch capabilities

13.3.2 Environment-hardened materials and structures

1. Low flammability materials
2. Puncture/abrasion resistant materials
3. Thermal protection/insulating materials
4. Blast/explosion abatement technologies
5. Lightning/Radar hardening of vehicle and components
6. ESD resistant materials/coatings - increase decay-rate of charged materials
7. Weather hardening of structures

13.3.3 Inspection, Anomaly Detection and Identification

1. Non-destructive, minimally intrusive inspection and evaluation electronics
2. Automated anomaly detection capabilities for ground and launch systems and processes

13.3.4 Fault Isolation and Diagnostics

1. Minimally-intrusive, non-intrusive monitoring technologies
2. Wireless interconnects
3. Wiring, harnesses, cables
4. Electronics, connectors, switches
5. Materials (coatings/polymers, adhesives, composites, insulation)
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13.3.5 Prognostics Technologies

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13.3.7 Communications, Networking, Timing, and Telemetry

1. Launch vehicle telemetry systems
2. Remote telemetry systems
3. Communication/Telemetry systems based on new spectrum (e.g. millimeter wave and optical)
4. On-demand dynamic frequency allocation
5. On demand communications
6. Universal comm beacon
7. Highly secure, access controlled flexible data networking (terrestrial and airborne)
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11. Adaptive data compression

13.4 Technologies to Improve Mission Safety/Mission Risk

13.4.1 Range Tracking, Surveillance, and Flight Safety Technologies

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7. Advanced vertical landing gear – variable density damping
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13.4.3 Weather Prediction and Mitigation

1. Single Authorative Source for weather data assimilation and prediction
2. 3D atmospheric electrical field measurement
3. Direct probing of the electric field in the clouds
4. 4D weather information integration for pilot and autopilot use

13.4.4 Robotics/Telerobotics

1. Machine vision
2. Remote repair capability
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13.4.5 Safety Systems

1. Advanced algorithms to predict failures
2. Advanced tools to assess risk posture
3. Autonomous "Safety Sentinels"
4. Human performance modeling
5. Advanced systems for Protection of Equipment
6. Advanced systems for protection of personnel

Key Technologies Identified

- **Low-loss cryogenic storage and transfer** (TABS 13.1.1)
- **Corrosion detection and prevention** (TABS 13.2.1)
- **Autonomous systems and integrated systems health management** (ground systems and moving ground to onboard systems) (TABS 13.1.3.7)
- **Intelligent, self-diagnosing/self-healing components and systems** (TABS 13.3.5.4 and 13.3.6)
- **Multipurpose models enabling distributed control and collaboration** (TABS 13.1.3)
- **Environmental protection and remediation** (TABS 13.2.2 and 13.2.3)
- **Weather effects detection and mitigation** (TABS 13.4.3)
- **Ground launch assist systems** (TABS 13.3.1)
- **Landing and recovery systems** (TABS 13.4.2)

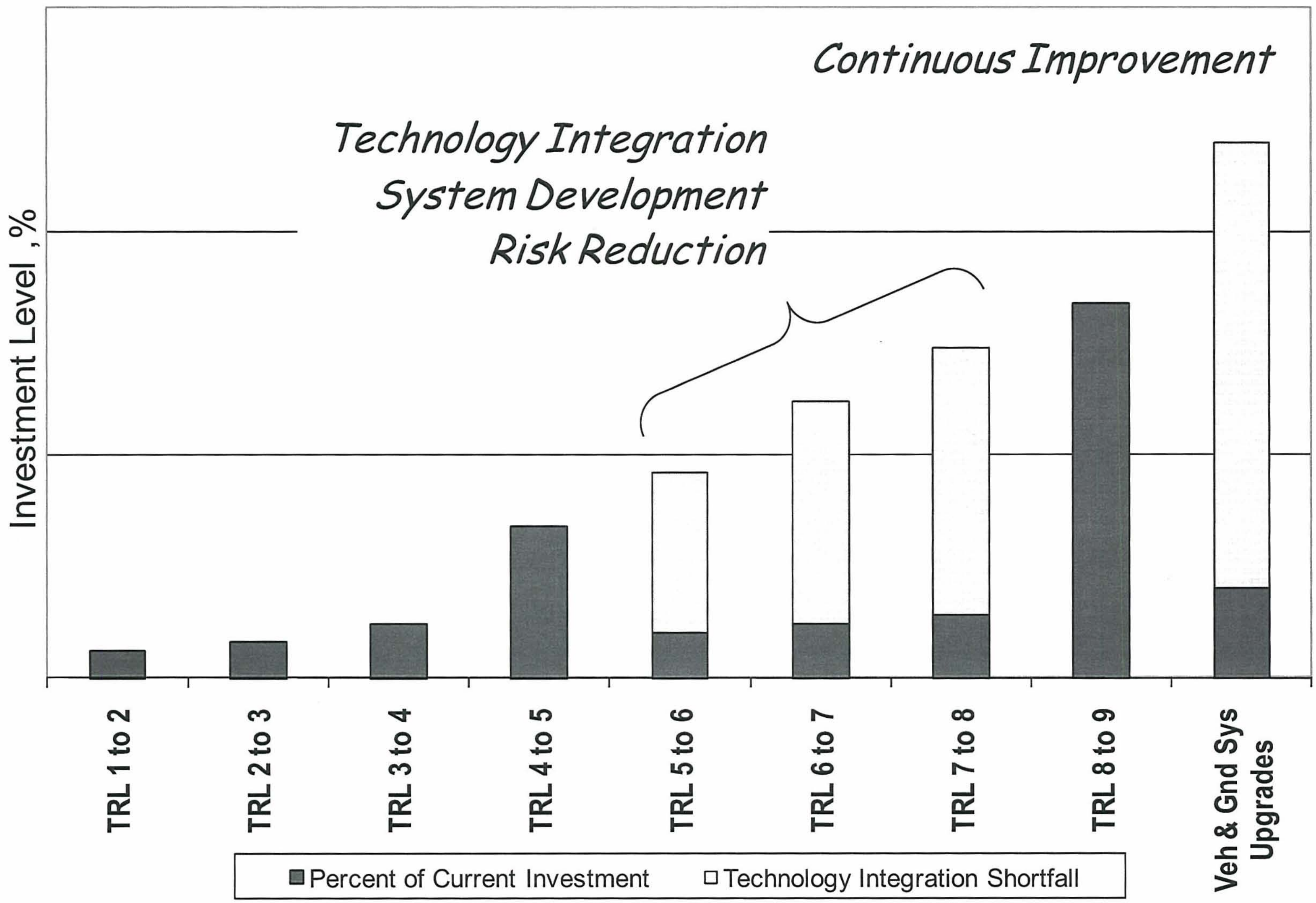
Corrosion Detection and Control

- Corrosion is a "silent killer" of the world's critical infrastructure and costs the world economy over $2 trillion annually
  - The total annual estimated direct cost of corrosion in the U.S. in 2010 was $578 billion—approximately 4.2% of the nation's Gross Domestic Product
- For NASA, the severe degradation of structures from corrosion (caused by exposure to high temperature, humidity, salinity, sunlight, or highly acidic launch exhaust, use of dissimilar metals, standing/trapped water, etc.) has resulted in significant ground operations corrosion-related costs.
- NASA can achieve significant cost savings, for the space program and for the nation as a whole, by developing and implementing new corrosion prevention, detection, and mitigation technologies that provide environmentally friendly (no toxic materials) corrosion resistant/protective materials, coatings, and systems
  - longer lasting and fewer reapplications required
  - lower maintenance/inspection costs
  - reduced corrosion related damage/structural failures
  - less environmental contamination

Corrosion Detection and Control Technologies

- *Enhancing current capabilities*: Smart, multifunctional, environmentally friendly paint system that detects and signals corrosion, mitigates corrosion, and self heals mechanical damage.
- Proactive corrosion control technologies will replace the current reactive state-of-the-art practice of repair and refurbishment after a failure or problem occurs
- *Enabling new, game-changing capabilities*: Autonomous, self-healing structures using corrosion-hardened materials that perform without degradation or the need for coatings or repairs; corrosion resistant structures
- Providing benefits for improving and protecting national infrastructure
  - Military weapon systems . (CC Tech and NACE Int. in cooperation with DoT and FAA, Sept 2001)
  - Army ground vehicles and Navy ships
  - U.S. oil and gas industry ageing infrastructure (rusting, corroded assets)
  - Other potential spinoffs/collaborators include the automotive, building, manufacturing, and housing industries, the Paint industry, and degrading transportation infrastructure

Need for Additional "Higher TRL" Investment



TA #13 Draft Roadmap briefing to the FAA/AIAA
Commercial Space Conference – Feb 2011

Ground and Launch Technologies Demonstrations

- In our existing Spaceflight Programs, sets of existing "Domain" Technologies have been integrated and validated for Ground and Launch operations

- Without comprehensive capabilities for full scale test and demonstration, new, individual technologies are overly constrained to be "one for one", drop-in replacements for an existing capability, without the ability to re-engineer HOW operations are conducted
  - This has severely restricted the ability for meaningful technology insertion

- To address this issue, a series of Ground and Launch Technology Demonstrations (GLTDs) are identified in TA #13 to integrate and test a bundled set of technology capabilities into an operationally relevant environment (TRL 6/7 and IRL 6/7). TRL-IRL-SRL Primer

Ground and Launch Technologies Demonstrations

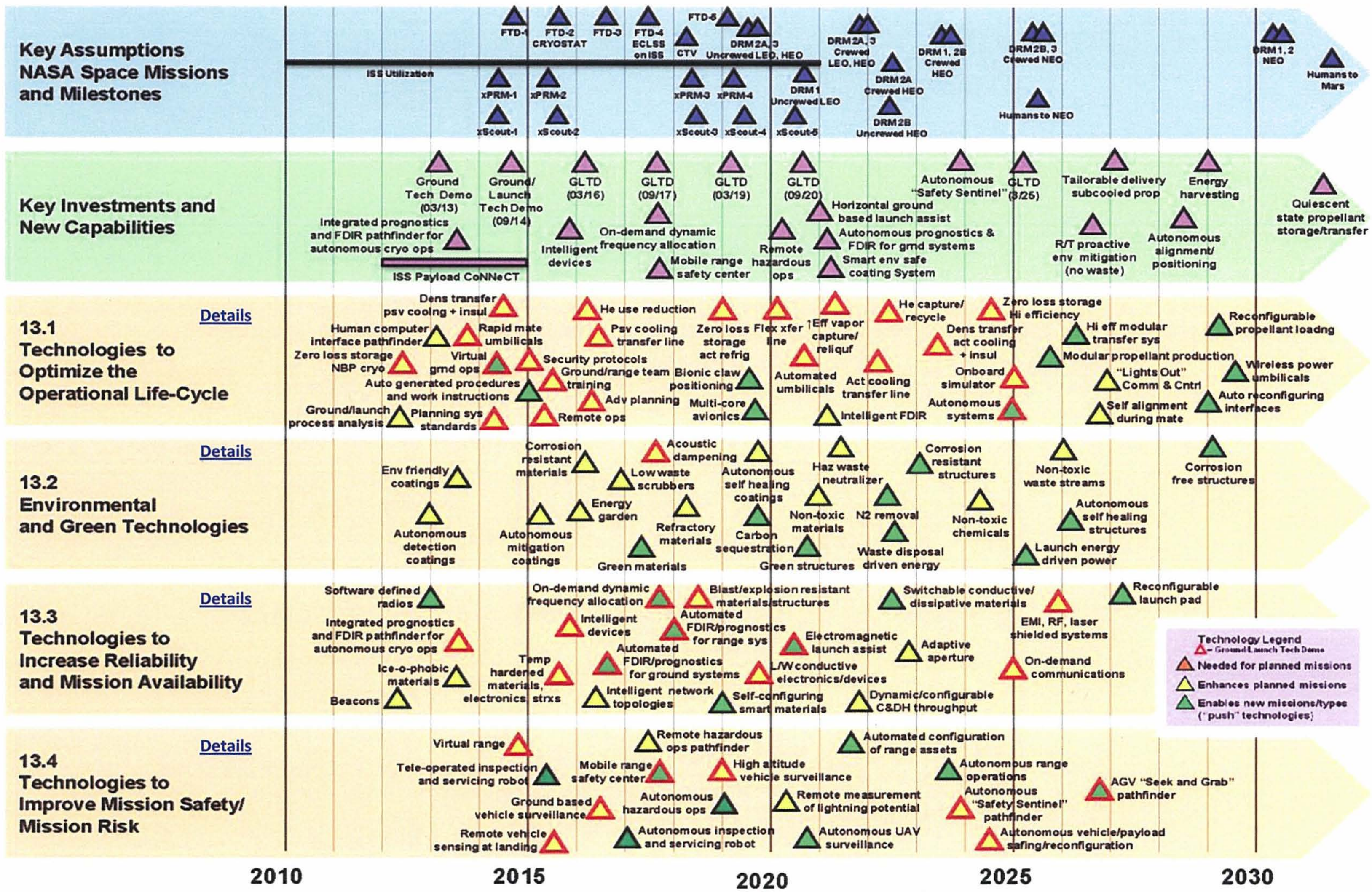
- Regularly scheduled technology demonstrations (approximately every 18 months) provide a deterministic and consistent ability for technologists, engineering and operations experts to collaborate for fielding demonstrations for advancing Technology and Integration Readiness of component technologies.

- GLTDs would showcase a distributed Ground Demonstration "Network" to utilize multiple locations (e.g., vehicle providers, commercial data centers, test stands and control rooms distributed across the country) collaborating for conducting distributed demonstration.

- Promising and emerging technologies that are proven via GLTD could then be incorporated into upcoming test flights, referenced for the planning and development of future missions, and/or retrofitted into upgrades to existing operational capabilities.

Technology Area Strategic Roadmap

Technology Roadmap: Ground and Launch Systems Processing



Summary

- Ground and Launch Processing Technologies enhance life on earth AND have a major impact on how we access space
  - GLPT are also directly applicable to building and manufacturing industries, weather forecasting, defense/homeland security, oil and gas industries, energy, hazardous operations
  - Can feasibly provide the cost breakthroughs to help realize routine, commercial space access
- The inter-relationships between Technology Readiness, Integration Readiness, and System Readiness drive the maturation of Ground and Launch Processing Technologies
  - "Ground and Launch Technology Demonstrations", which integrate promising technologies into an operationally relevant environment, can maximize the benefits of our Agency's technology programs
- For more information on this Roadmap, and to provide input and public comment, please visit the National Research Council Site or support the public workshop in March:
  - http://sites.nationalacademies.org/DEPS/ASEB/DEPS_059552

BACKUP

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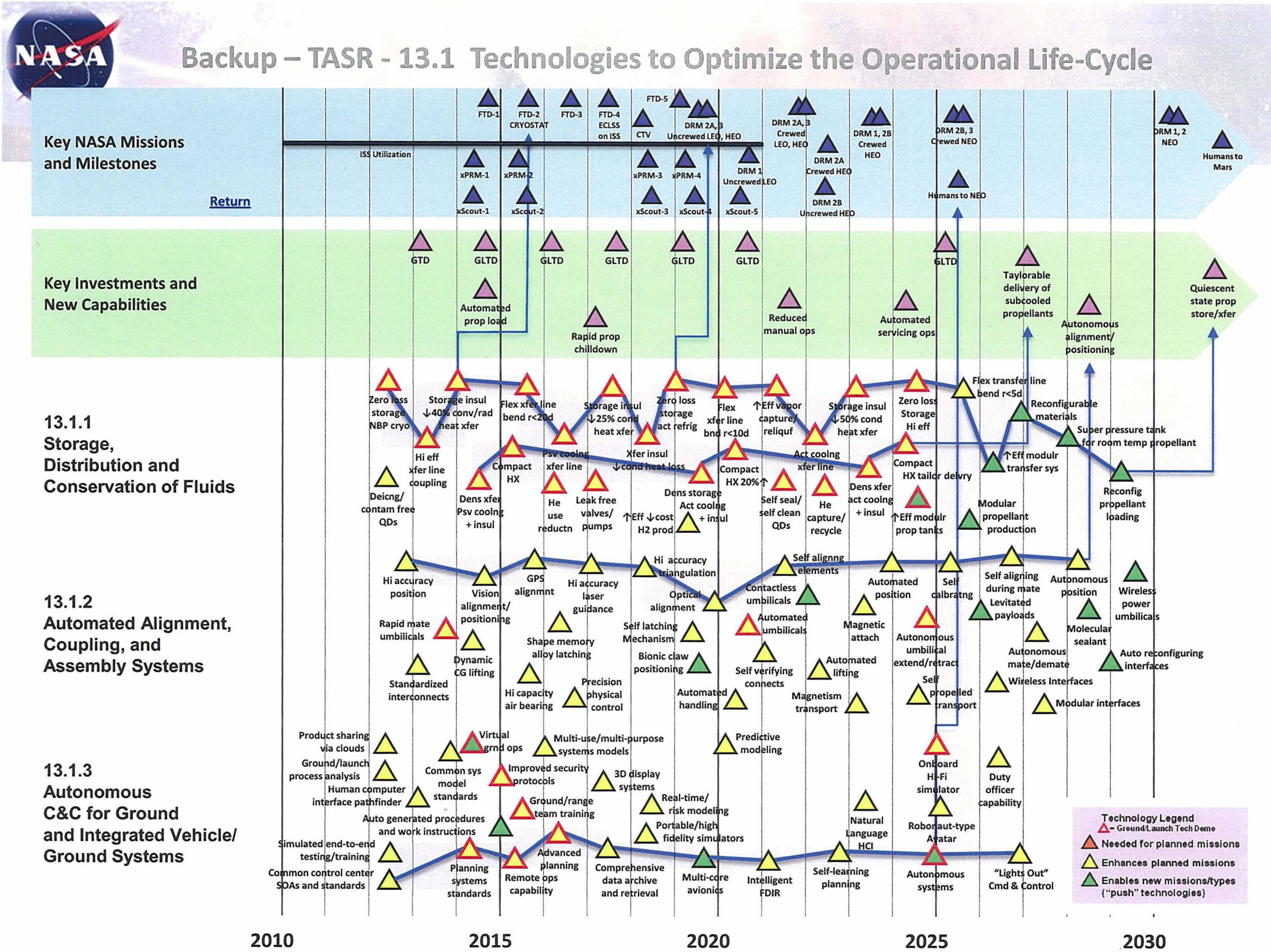
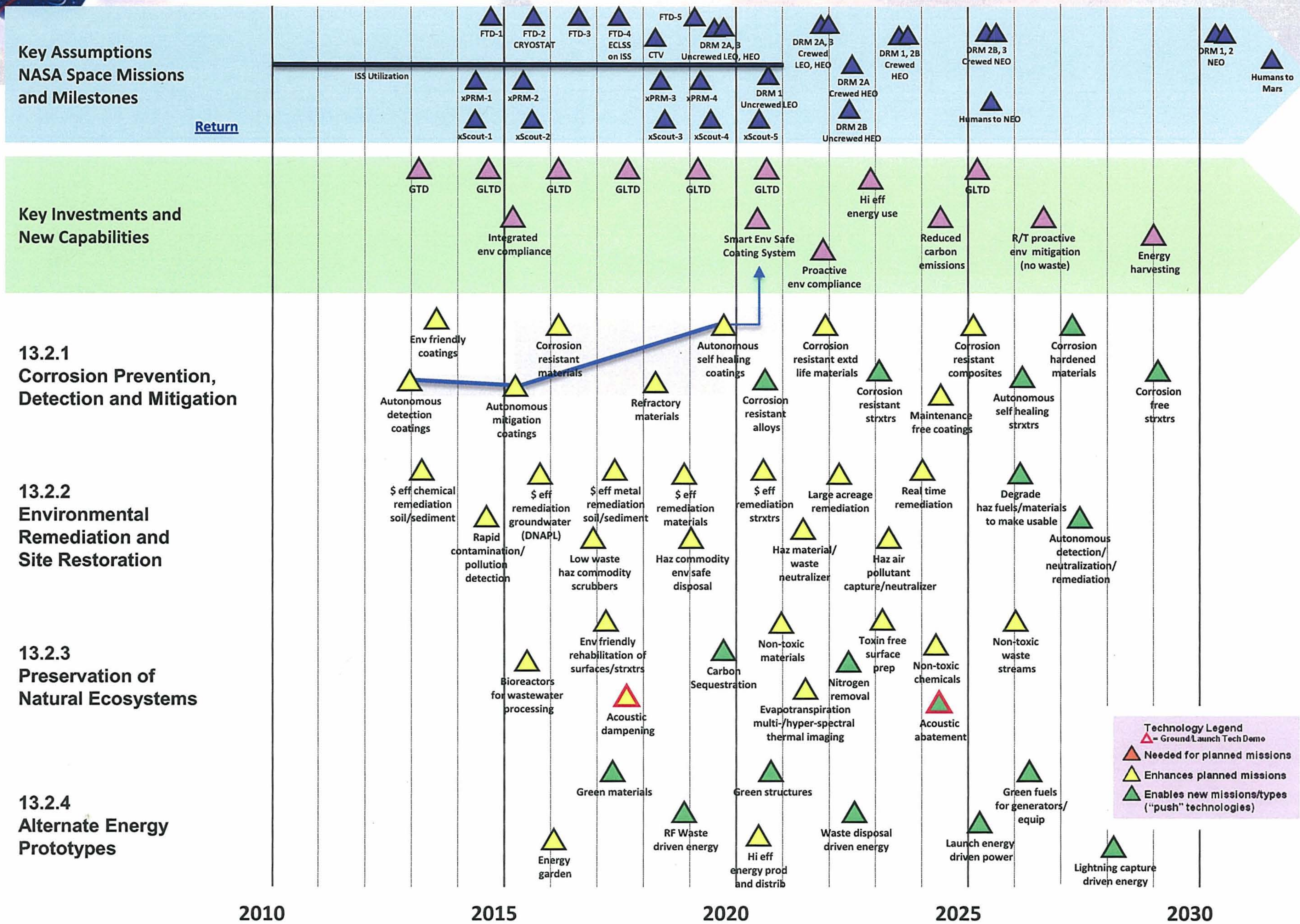
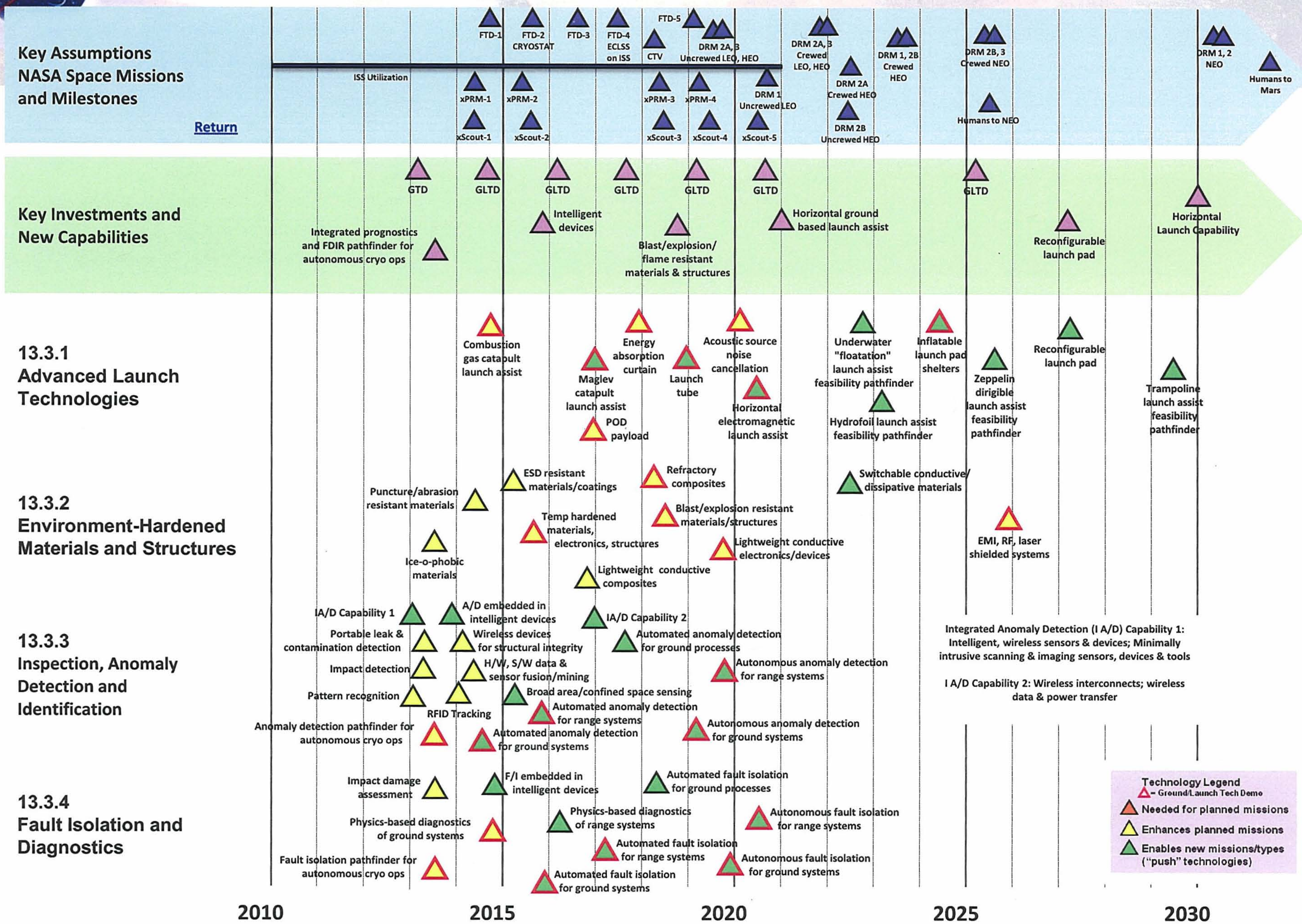
Backup – TASR - 13.1 Technologies to Optimize the Operational Life-Cycle



Backup – TASR - 13.2 Environmental and Green Technologies



Backup – TASR - 13.3 Technologies to Increase Reliability and Mission Availability (1 of 2)



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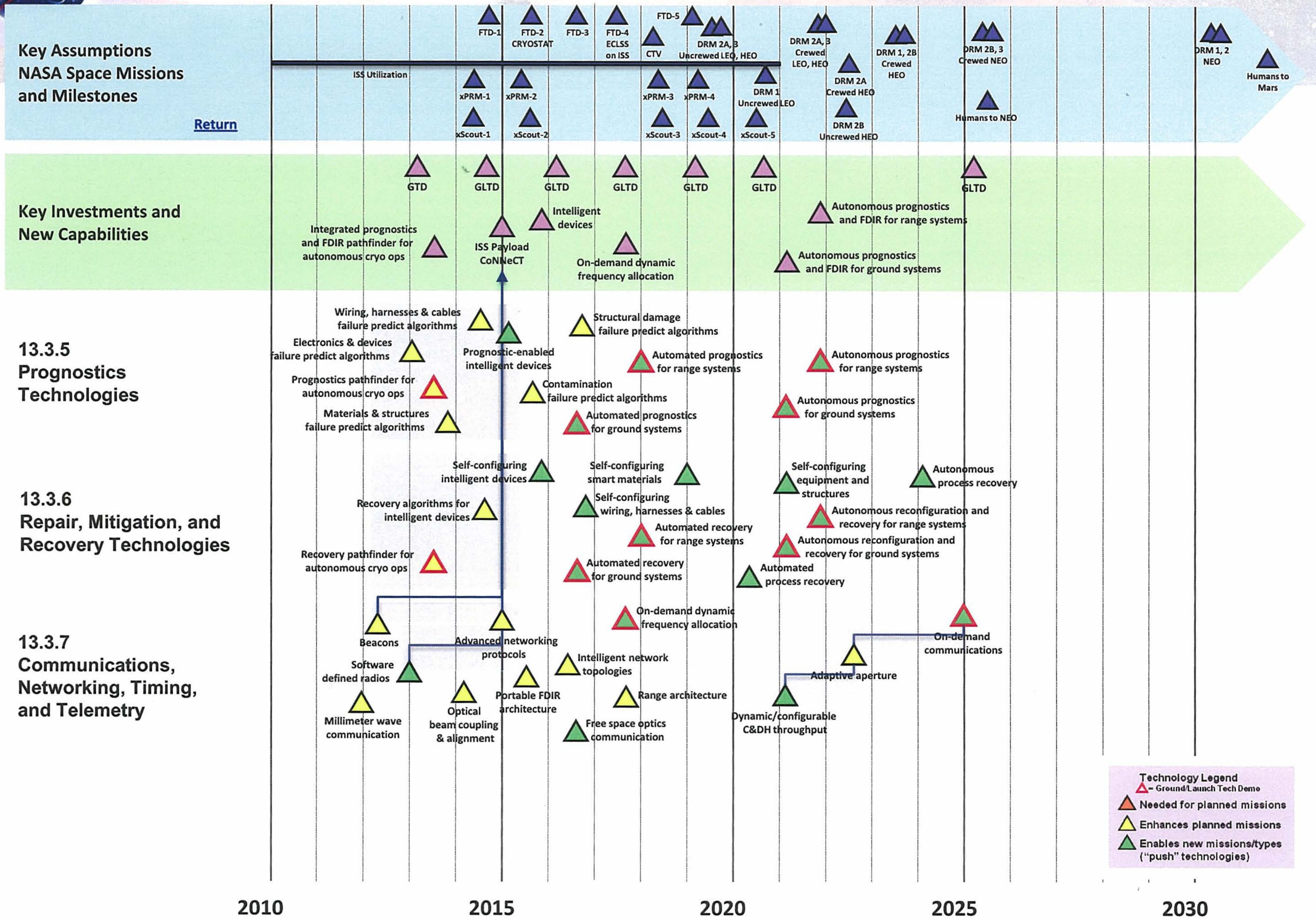
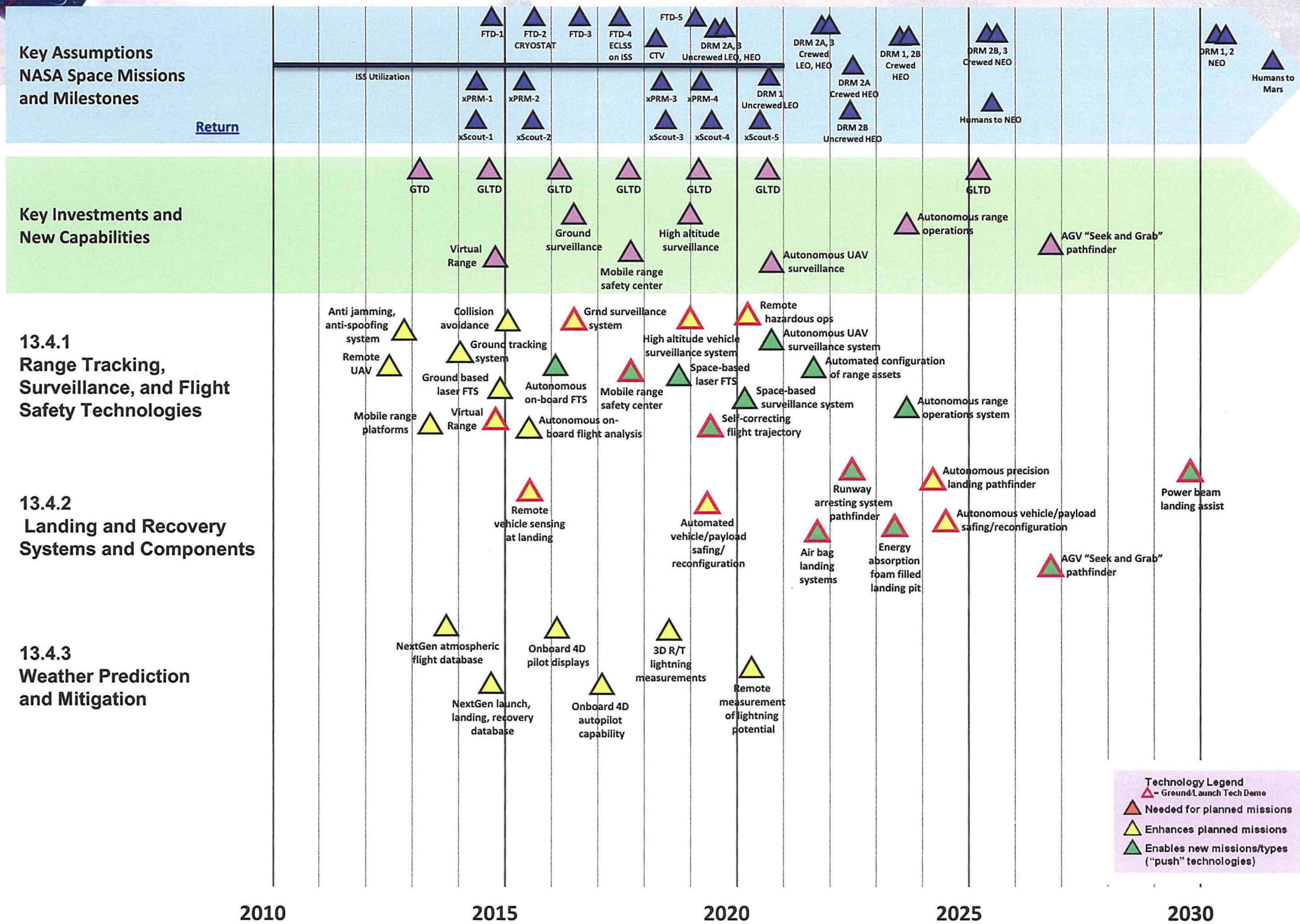
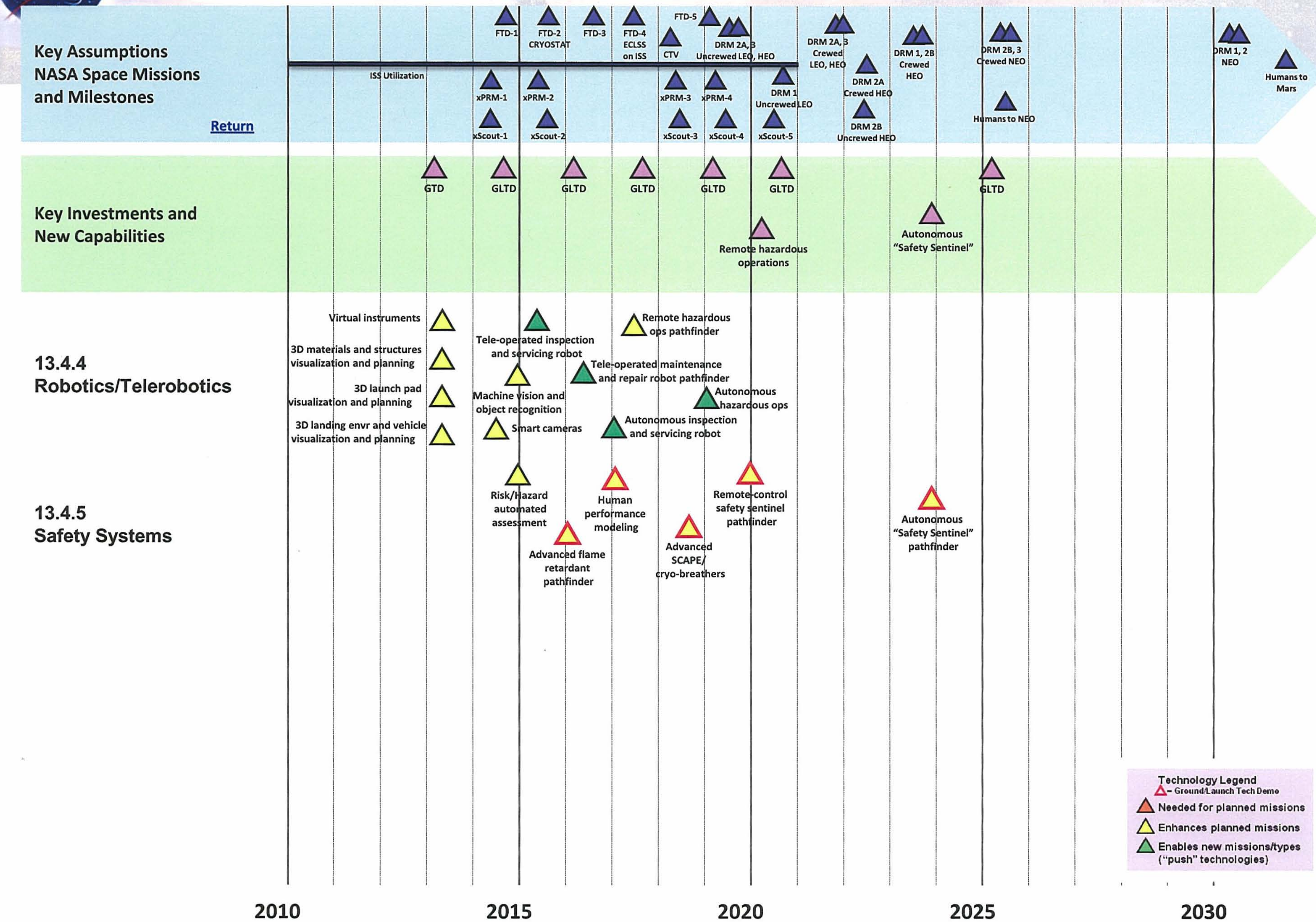


Backup – TASR - 13.4 Technologies to Improve Mission Safety/Mission Risk (1 of 2)



Backup – TASR - 13.4 Technologies to Improve Mission Safety/Mission Risk (2 of 2)



TRLs, IRLs and SRLs

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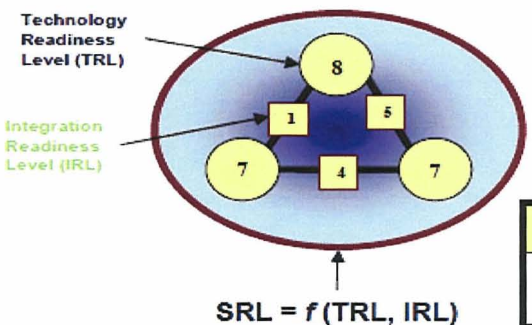
What is Integration Readiness Level?



A systematic measurement of the interfacing of compatible interactions for various technologies and the consistent comparison of the maturity between integration points.

Integration – the combining and coordinating of separate components into a seamless unit – interfacing the compatible interactions of various technologies together

IRL	Definition [9]
7	The integration of technologies has been ***verified and validated*** with sufficient detail to be actionable.
6	The integrating technologies can ***accept, translate, and structure information*** for its intended application.
5	There is sufficient ***control*** between technologies necessary to establish, manage, and terminate the integration.
4	There is sufficient detail in the ***quality and assurance*** of the integration between technologies.
3	There is ***compatibility*** (i.e. common language) between technologies to orderly and efficiently integrate and interact.
2	There is some level of specificity to characterize the ***interaction*** (i.e. ability to influence) between technologies through their interface.
1	An ***interface*** (i.e. physical connection) between technologies has been identified with sufficient detail to allow characterization of the relationship.

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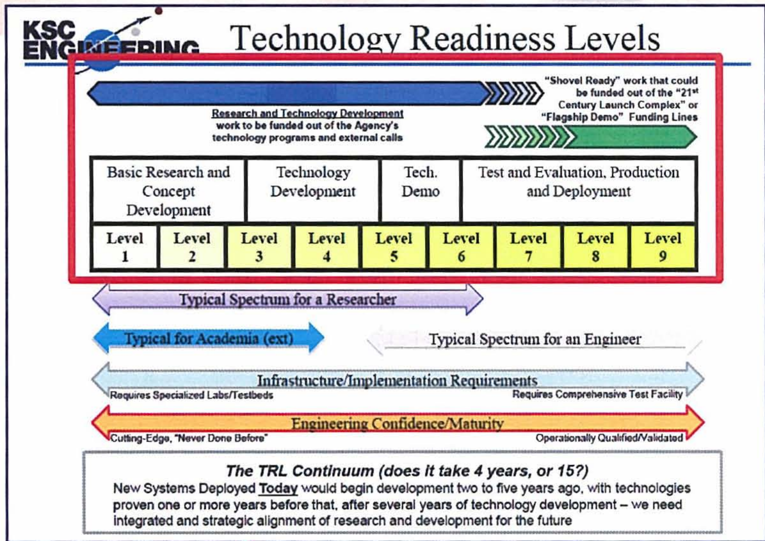
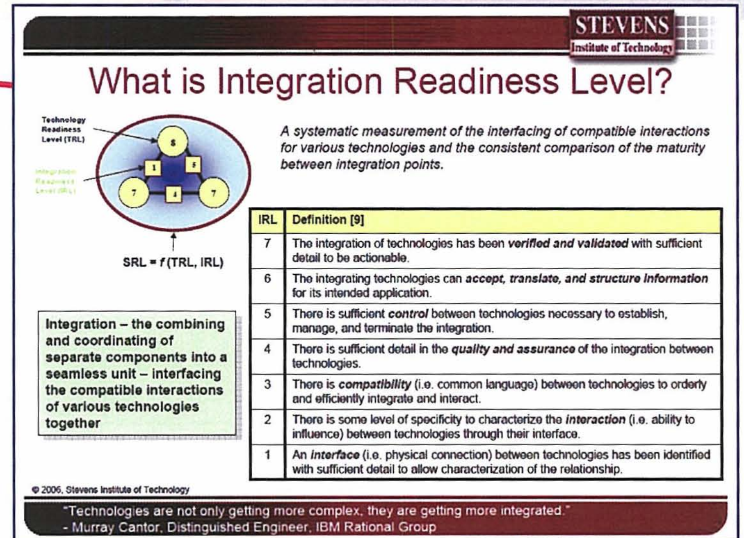
"Technologies are not only getting more complex, they are getting more integrated."
- Murray Cantor, Distinguished Engineer, IBM Rational Group

TRLs, IRLs and SRLs



Technology Readiness



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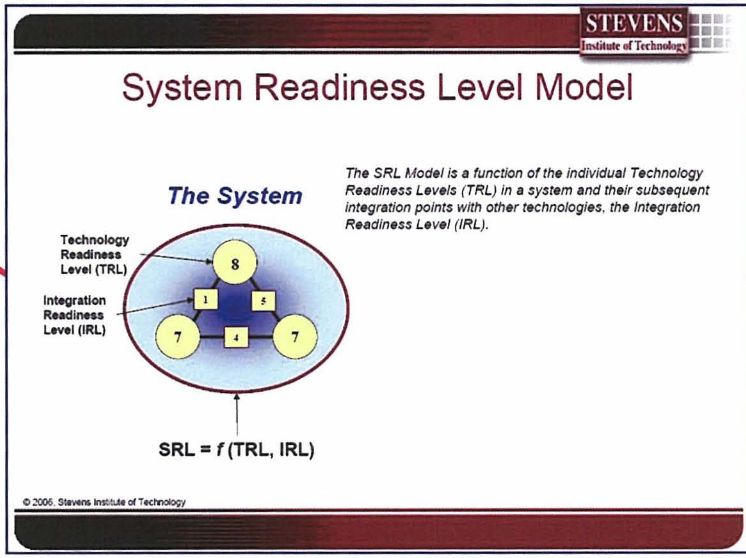
Integration Readiness



System Readiness

Return

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