NASA Transformational Spaceport and Range Capabilities Roadmap
Interim Review
to
National Research Council External Review Panel

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Agenda

- Overview/Introduction
- Roadmap Approach/Considerations
  - Roadmap Timeline/Spirals
  - Requirements Development
- Spaceport/Range Capabilities
  - Mixed Range Architecture
- User Requirements/Customer Considerations
  - Manifest Considerations
  - Emerging Launch User Requirements
- Capability Breakdown Structure/Assessment
- Roadmap Team Observations
  - Transformational Range Test Concept
- Roadmap Team Conclusions
- Next Steps

National Space Transportation Policy

Signed December 2004

- National Policy Focus on Assuring Access to Space

  “The Federal space launch bases and ranges are vital components of the U.S. space transportation infrastructure and are national assets upon which access to space depends for national security, civil, and commercial purposes. The Secretary of Defense and the Administrator of the National Aeronautics and Space Administration shall operate the Federal launch bases and ranges in a manner so as to accommodate users from all sectors; and shall transfer these capabilities to a predominantly space-based range architecture to accommodate, among others, operationally responsive space launch systems and new users.”

- ***NASA seeks to link the Transformational Spaceport and Range Capability Roadmap activity with the new National Space Transportation Policy direction as we develop a National Implementation Strategy***

Roadmap Tasking

The President's Commission on Implementation of the United States Space Exploration Policy Report Finding #4 states:

- *"The Commission finds that successful development of identified enabling technologies will be critical to attainment of exploration objectives within reasonable schedules and affordable costs."*
  - *"Transformational spaceport and range technologies – launch site infrastructure and range capabilities for the crew exploration vehicle and advanced heavy lift vehicles."*

NASA Capability Roadmap Charter, Phase 1:

- During this phase, technical experts both internal and external to NASA will provide the technical knowledge and expertise in the development of roadmaps which identify the capabilities that are needed to meet the missions of the Agency.

- The capability roadmap team will identify and analyze each of the associated technologies and assess the capability performance afforded by the current state of the art, the performance level needed by the strategic mission and trace the development required.

Roadmap Team Membership

- Karen Poniatowski, NASA HQ/Space Operations, NASA Chair
- Maj.Gen. (ret) Jimmey Morrell, Former USAF/AFSPC, External Co-Chair
- Col. Dennis Hilley, OSD/NII Space Programs, External Co-Chair
- Carole Flores, FAA, Manager, Licensing and Safety Division, Member
- Jim Costrell, NASA HQ/Space Operations/Space Communications, Member
- Jim Heald, NASA Kennedy Space Center, Member
- Bob Sackheim, NASA Marshall Space Flight Center, Member
- Bruce Underwood, NASA Goddard/Wallops Flight Facility, Member
- Tom Maultsby, Consultant, Member

Overarching Observations

- **The Transformational Spaceport and Range Capability Roadmap task is unique from other capability roadmaps, in that:**
  - NASA is one of many users of an existing capability
  - There is a broad diversity of current and potential providers of the capability: federal, state, commercial
  - NASA requirements are in various stages of identification and development
  - NASA Space Exploration related requirements may become a driver for new technology but those requirements are not yet matured
- **Key task is to identify NASA- unique requirements and any new technology that might be warranted to meet the Space Exploration Vision**
  - CEV requirements for human transport: Under definition
  - Cargo requirements for heavy lift transportation: Under trade studies considering evolution of existing shuttle and expendable systems as well as clean sheet approaches
  - Robotic requirements: e.g., Prometheus requirements under trade study and definition
- **Spaceport Roadmap will be driven by other strategic and capability roadmaps**
  - This roadmap's major output at this stage in the Space Exploration Vision definition will be a statement of capabilities and identification of potential paths for future technology investments
- **This is a continuous process and will need to be revisited as the Space Exploration requirements affecting public safety and customer needs at the launch site(s) evolve and mature**

Institutional Considerations

- Implementation of the Space Exploration Vision will involve the resources of NASA Centers , other government agencies (e.g., USAF) and state and emerging commercial capabilities
- Each NASA Center will likely have certain upgrades, improvements, and possibly responsibilities that will be seen as Space Exploration driven
- Affected organizations will want many of these met by the ranges as “common” requirements and will want them in the roadmap
- A challenge is to deal with the separate individual interests of institutions to operate in a “desired ideal end state” vs from the spiral/phased needs
- Investments in spaceport and range capabilities that support the general user community should be considered for institutional funding
- Customer-unique requirements should be expected to be funded by the customer

Roadmap Approach

- Assessed the national spaceport and range capabilities (Federal, state, commercial) with focus on USG investment options for space launch as well as test and evaluation
  - The bulk of Space Exploration-related launch activities will likely be on the U.S. east coast
    - CEV and potential heavy lift operations
  - Focus of this Roadmap is Earth-based range
  - Non-Earth-based concept (e.g., Lunar base) is downstream excursion for Spiral 3 horizon or beyond

- Solicited/Reviewed User issues/requirements drivers
  - Requirements will drive investment options

- Coordinated with Strategic Transportation Roadmap and Communications and Navigation Capability Roadmap
  - Preliminary definition of S&R Roadmap interface with the AFSCN, NASA Space Communications and launch requirements
  - Range requirements derived from that work

- Used existing national working group reports as technology references for investment considerations

- APIO guidance provided framework for Roadmap efforts

- The team defined two time periods: present to 2015 and 2015 to 2030

Issues in Conducting the Roadmap

- Defining the terms: Spaceport, range, transformational
- Priorities and sources of requirements that drive technology investments with measurable performance enhancements to end users
- Definition of the a Space Based Range and what it really implies
- How to relate the Advanced Space and Range Technology Reports technology development concepts to requirements
- Balancing individual institutional equities within the larger framework of Space Exploration

Definitions: Considerations

- There is no common purpose spaceport in existence today, although FAA has attempted to craft notional definitions
- Commercial spaceports in the future that could support space exploration are not excluded…..however focus in near term is on existing capabilities
- The quest for "Common user requirements" for the Federal launch bases or Centers that might support space exploration are extremely diverse and far from common at this time
  - The facilities and infrastructure that exist today have evolved based on requirements derived from common user needs at a launch site for spacecraft, vehicle operations and public safety
  - Mission specific requirements have to date been identified by the end-user and may or may not be permanently added to the common user structure
- Space exploration programs are not yet defined and will mature over time- this is especially true for Moon, Mars and Deep Space needs

Roadmap Definitions

- Primary functions of a “Range”:
  - Ensure public safety from hazardous operations
    - Ensure operational infrastructure/resources for launch support Telemetry coverage and launch communications
- “Spaceport” refers to collection of customer services/support at a launch site
  - Launch vehicle and Spacecraft processing, “customer” services and access, logistics, communications, etc
  - Launch countdown operations and contingency planning
  - Spacecraft and vehicle
  - Landing and Recovery operations
  - Institutional Infrastructure
- Federal Ranges today encompass a mix of Range and Spaceport functionality
- For purposes of this Roadmap assessment, the focus is centered on two primary requirements drivers:
  - Public Safety = Range
  - Customer support/service infrastructure = Spaceport

Transformational Definition

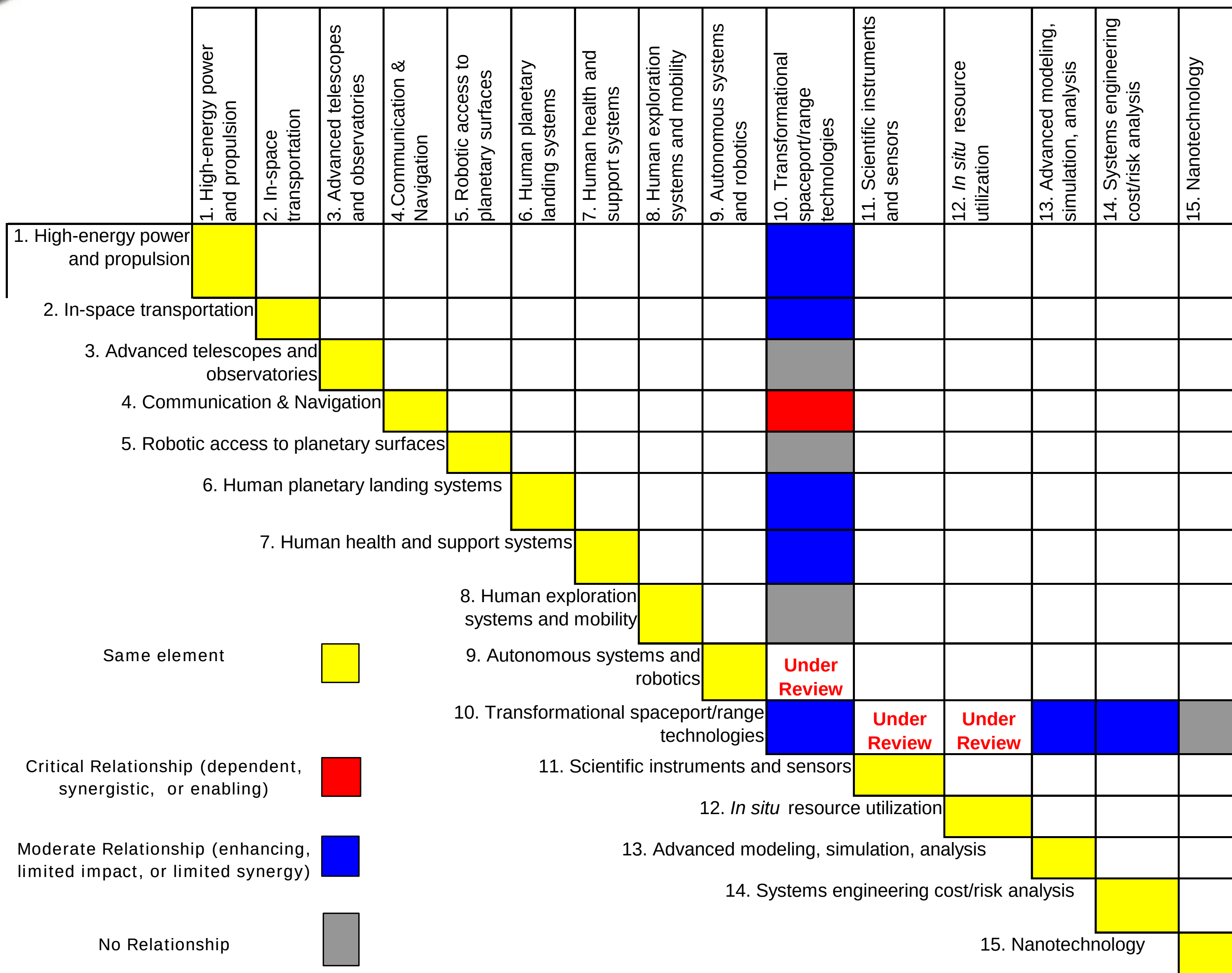
- Specific task focus was on “transformational” investments or actions to meet current and future requirements
  - Goal is to improve capabilities, safety, and performance of existing and future spaceports/ranges
  - Recognizing understanding of CEV and heavy lift requirements at the launch site and range are still evolving

- Defined by Spaceport/Range Capability Roadmap Committee as:
  - Investments or actions that could lead to significant improvements in spaceport/range performance or capabilities, tied to current/future requirements
  - Actions that would increase range effectiveness

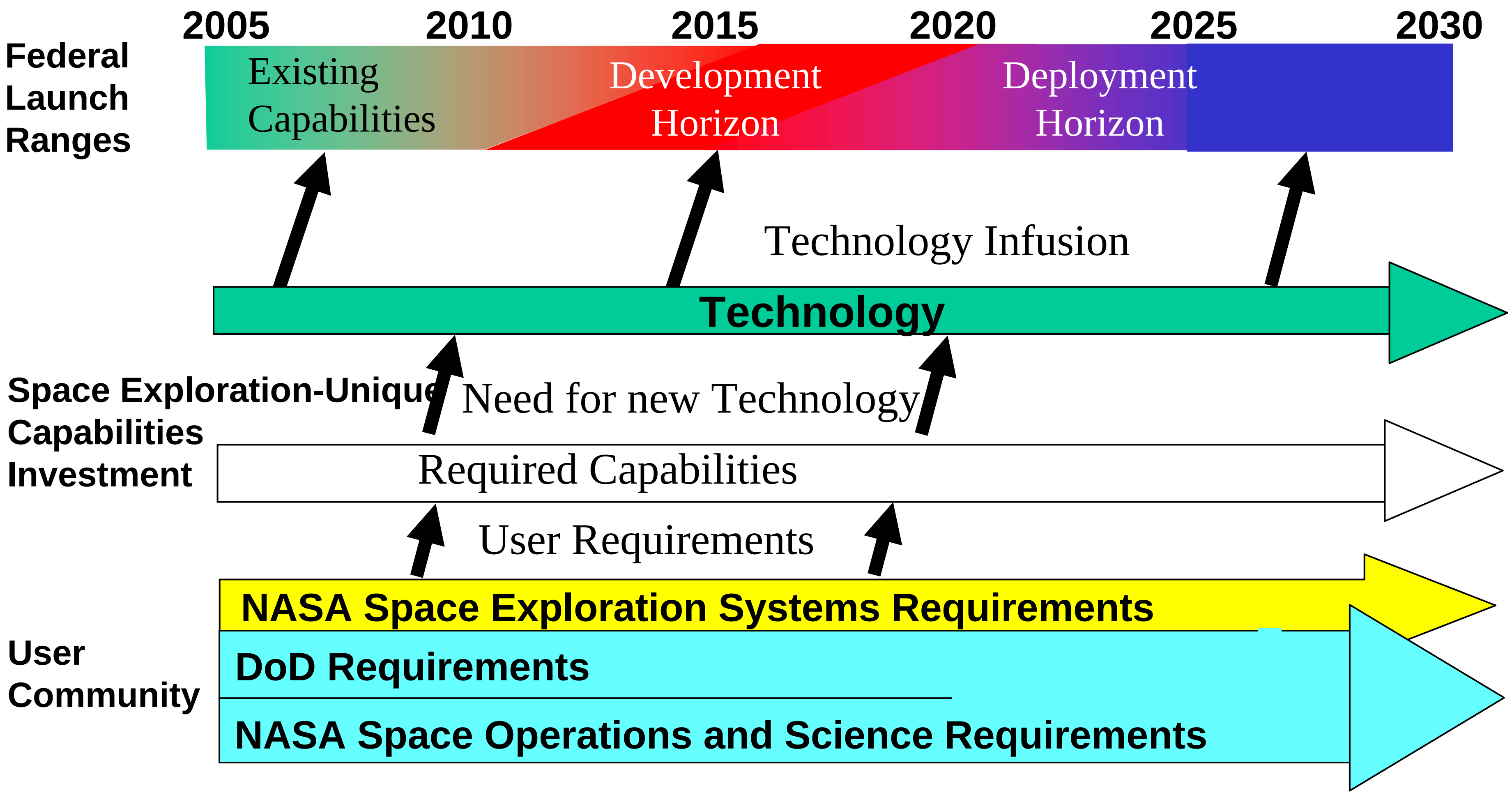
- The above could have affectivity in the near or long term

Crosswalk Matrix Ratings

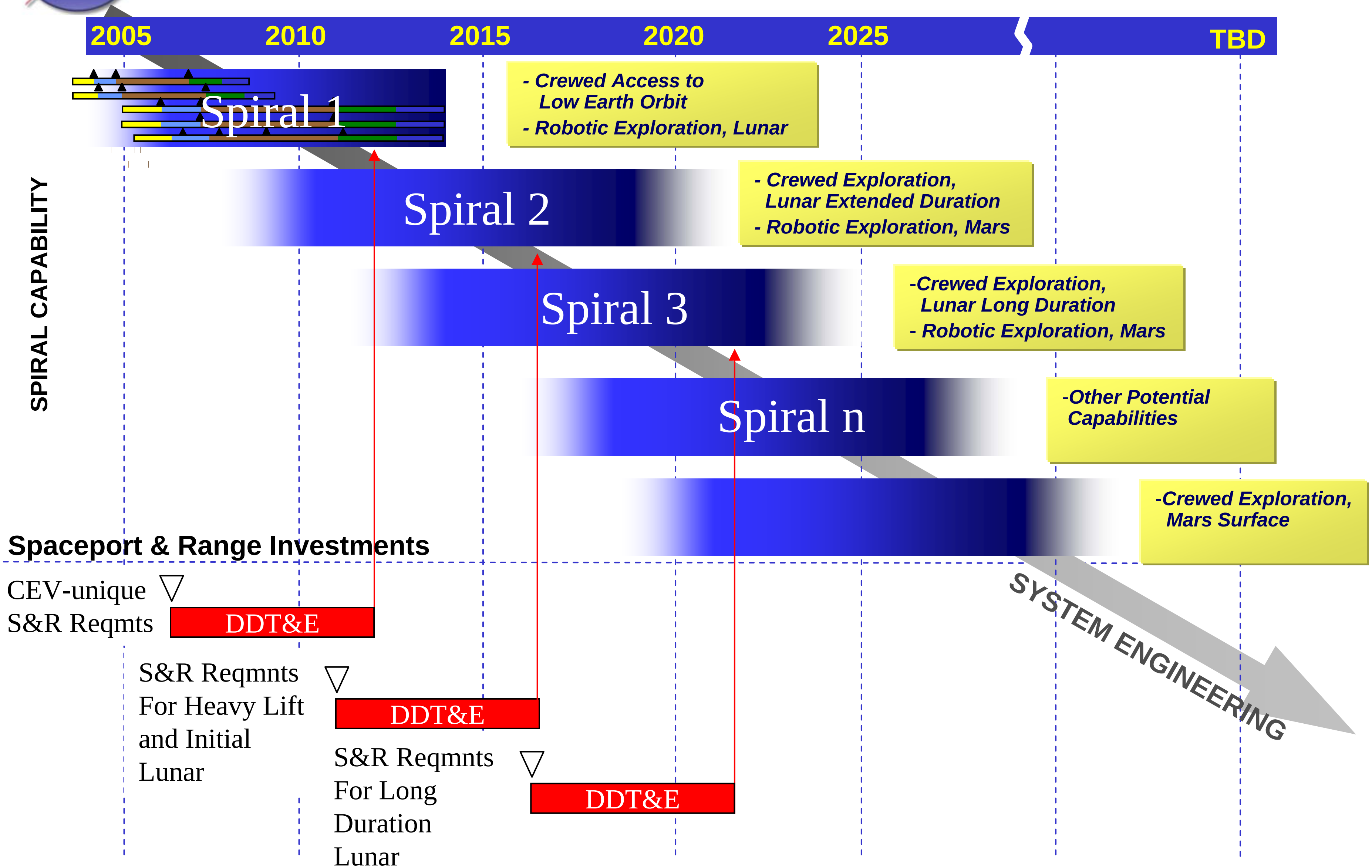
Work In-progress



Roadmap Timeframes



S&R Capabilities Development relative to Space Exploration Spirals



Common Services and User Unique Requirements

- Historically, process has differentiated between what a range/launch site can best and should provide versus what the individual user should be expected to bring with the mission
  - Traditionally programs that require significant facility support or new infrastructure pay for the dedicated facility or capability on the range
  - This approach is likely best for support to the the Space Exploration initiative, considering fiscal reality
  - Also recognizes that these costs would never be supported in the range agencies' budgets – it would simply overwhelm the process

- Many functional common services are Rang operator's requirement to provide public safety and expand to support the users' needs for similar activity

- In all cases, requirements fall into the areas of either public safety or customer support

Technology Issues

- Some technology concepts today are not clearly driven by a stated firm specific mission or vehicle concept
- Need a link to requirements to enable development of a prioritization process of candidate technologies available
- The timeline for a presumed requirement continues to evolve
- Many technology concepts that might be feasible may not be attributable to “firm” requirements, but may be a need that makes sense from a multi-user standpoint.
  - Need to balance technology-push –vs- technology-pull
  - There is value in enabling (funding) technology R&D efforts for broad-based spaceport/range affectivity

ARTWG & ASTWG

Advanced Range Technology Working Group (ARTWG):

- Response to Presidential Directed OSTP & NSC Report, *"The Future Management And Use Of The U.S. Space Launch Bases And Ranges,"* February 2000
- Focus on next-generation range technologies
- MOA between NASA/Code M, and AF Space Command to jointly develop strategy
- Co-Chairs from NASA/KSC & AF Space Command

Advanced Spaceport Technology Working Group (ASTWG):

- Focus on next-generation ground processing technologies
- Chaired by NASA KSC, Vice Chair Executive Director Aerospace States Association

- Created forums for interchange among representatives from civil, commercial and national security sectors who have an interest in range and spaceport technology
  - Focused on new technology development
  - Emphasis on common needs and standardization
- Both forums have recently published reports which identify key capabilities and technologies for consideration as requirements for space exploration are developed

ASTWG and ARTWG
Contributions to the Roadmap Process

- Both Working Groups have made a major contribution to enhancing the understanding of the functions and operations of both spaceports and ranges by providing forums for routine interchange
  - Sought to target mix of government ranges, range users, and commercial spaceports
  - Groups sought to identify broad range of candidate technologies that could improve ranges and spaceports
- Both Working Groups are formulating investment strategies based on notional business cases and cost-benefit analysis which can then be tied to specific requirements
  - Common user requirements
  - User unique requirements…Space Exploration
- Process to prioritize requirements within and across user communities and then link to achievable performance metrics is a necessary next step to focus future investments for civil and national security communities and commercial community as market demand warrants

Roadmap Requirements Development Discussion

- ARTWG and ASTWG framed all activities that occur as either a range or spaceport function
  - Useful construct for technology and planning discussions
  - Input needs tailoring for this Roadmap as ARTWG/ASTWG did not identify the lines of responsibilities between the USAF and NASA and the rest of the user community
  - Attempts to align commercially funded spaceports and Federally funded spaceports/ranges requirements as the same

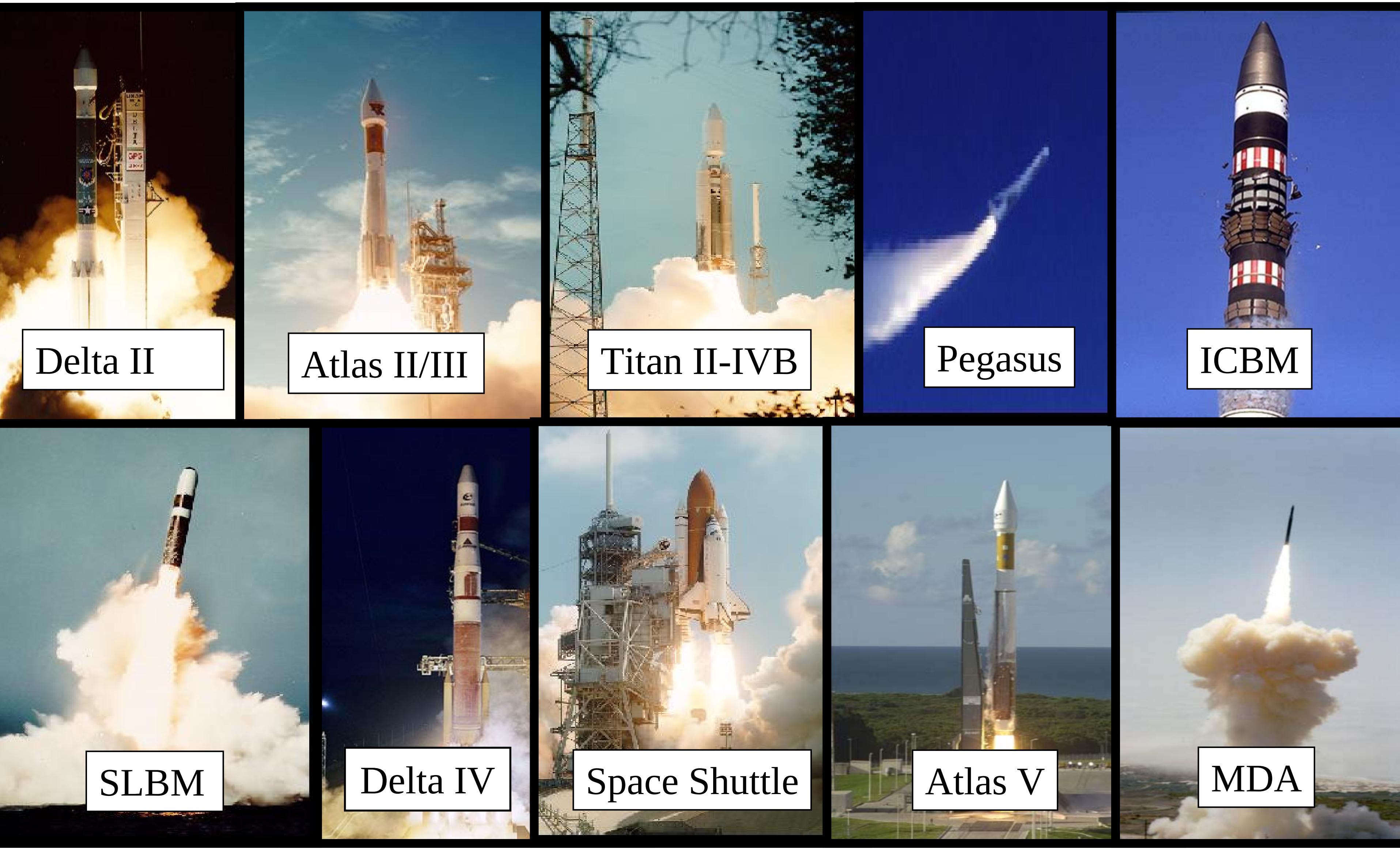
- "Commercial spaceport" roles in Space Exploration are expected but not definable at this time

- The roadmap assessment sought to identify where the highest capability pay offs exist for Federal ranges/launch sites with opportunities for application to other sites as appropriate downstream

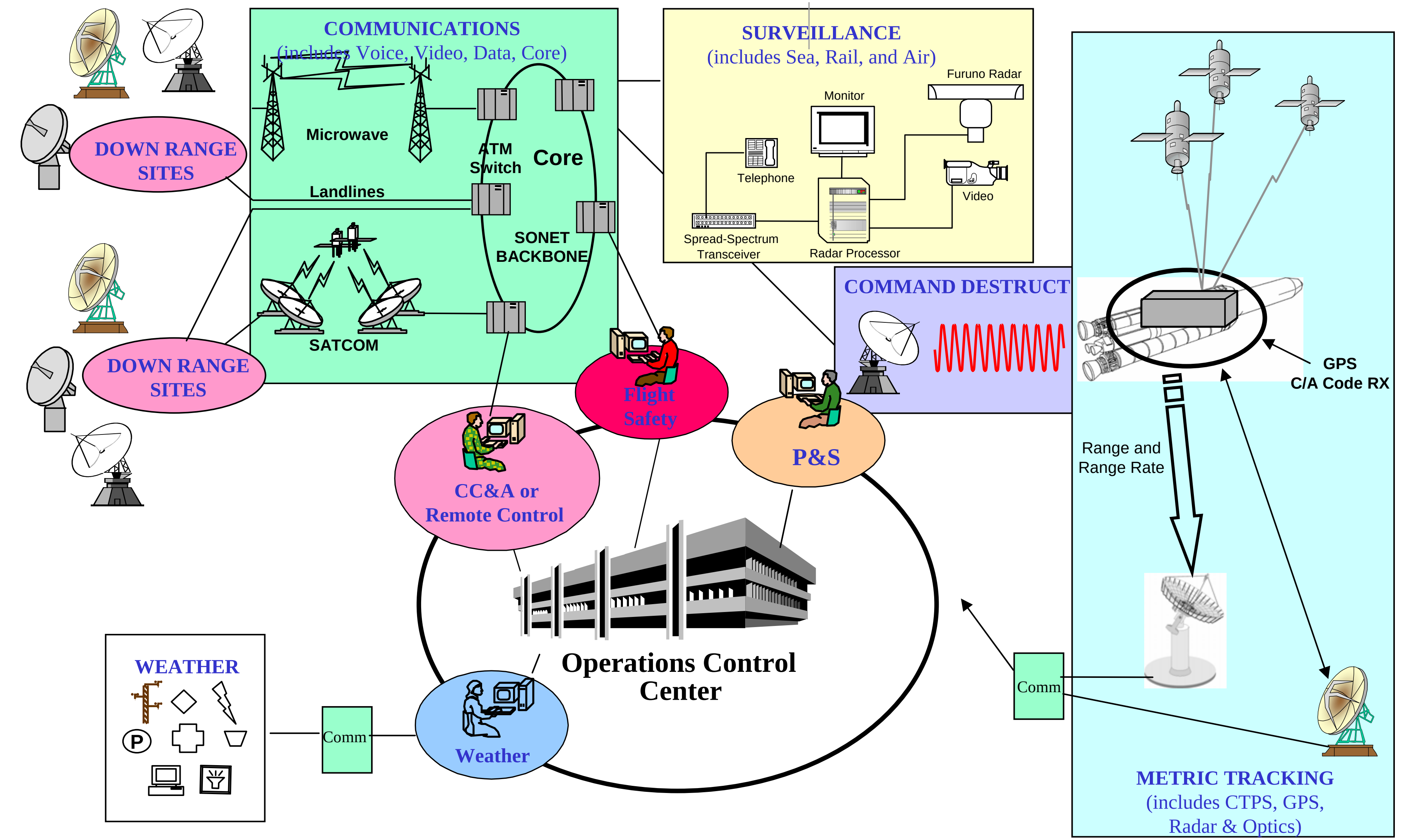
Current Ranges and Capabilities

National and Commercial

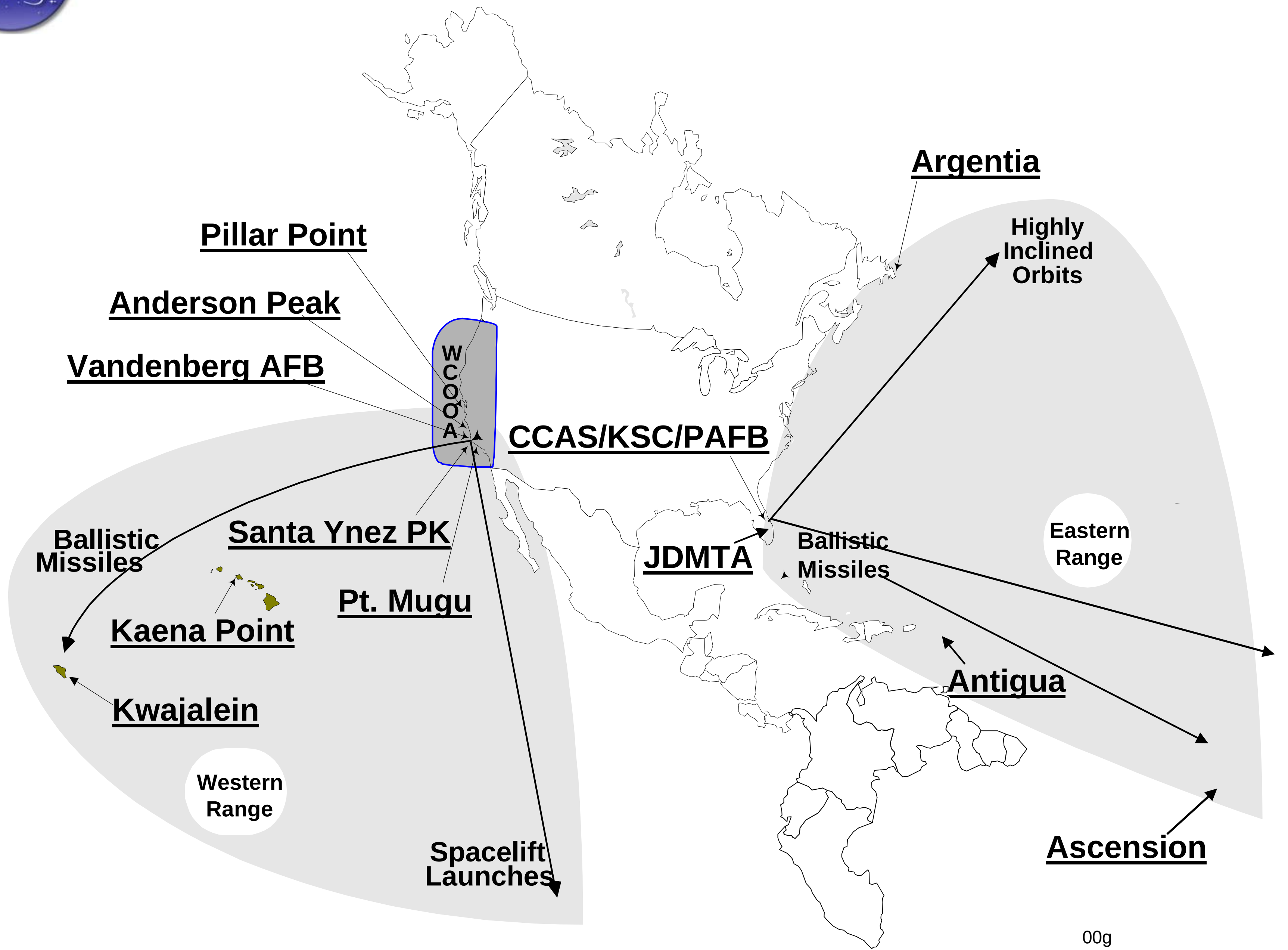
Examples of Launch Vehicles Supported



Current Federal Range Capabilities



Range Coverage



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Eastern Range
Space Launch Complexes and Payload Processing

- CCAS - Air Force
  - Titan Integrated Transfer Launch (ITL) Area
  - SLC 40 - Titan IV, IUS or Centaur
  - SLC 17 A&B - Delta II
  - SLC 41 - EELV (Atlas V)
  - SLC 37 - EELV (Delta IV)
  - Skid Strip - Pegasus
- CCAS - Navy
  - Complex 46 - Athena I/II
- KSC - NASA
  - Space Shuttle ITL Area
  - Complex 39 A&B - Space Shuttle
- Payload Processing
  - GPS, DSCS, SCIF

Western Range
Space Launch Complexes and Payload Processing

- Space Launch Complexes
  - SLC 4E - Titan IV, IUS or Centaur
  - SLC 4W - Inactive
  - SLC 2W - Delta II
  - SLC 3E - Atlas IIA/IIAS/IIIA, EELV (Atlas V)
  - SLC 3W – FALCON I
  - SLC 6 - EELV (Delta IV)
  - Pegasus

- Payload Processing
  - Astrotech
  - SSI @ IPF
  - Bldg.1610
  - Bldg. 836

Current Capabilities

NASA Wallops Flight Facility Range

Wallops Research Range Overview

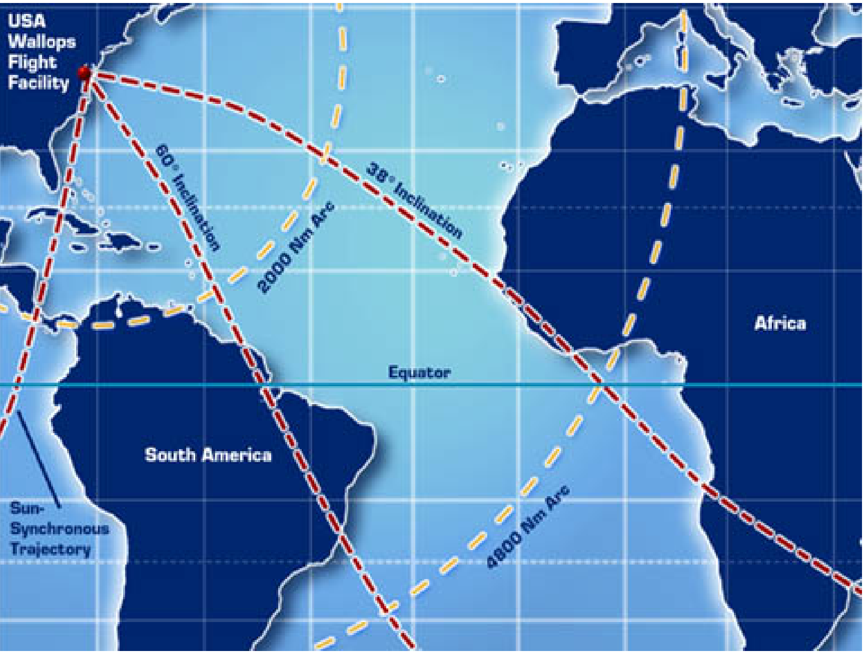
Launch Areas
- 2 Orbital Launch Complexes (active)
- 6 Suborbital Rail Launchers
- 3 Primary & 1 UAV Runways
- 3 Mobile Range Rail Launchers

Processing Facilities
- 2 Multi-Bay Hazardous Processing Facilities
- 5 Payload Processing Facilities

Instrumentation
- 1 Range Control Center & 1 Aeronautical Control Center
- 4 Fixed S-Band Telemetry Antennas
- 3 Fixed C-Band Tracking Radars
- 3 UHF Command Transmitters (redundant)
- 2 Ground & 1 Airborne Surveillance Radars
- Optical/Video
- Communications
- Weather Measuring & Forecasting
- Range Timing
- Real-Time Data Processing

Mobile Range Capabilities
- 3 Rail Launchers
- 2 Range Control/Transmitter Systems
- 1 UHF Command System
- 5 S-Band Telemetry Antennas
- 3 C-Band Radars
- 4 Power Generator Systems

Wallops Research Range Facts



- Range History
  - First Launch July 1, 1945
  - 15,000 total launches
  - 29 orbital missions
  - 600-700 Range events annually (all projects)
  - 35-50 launches annually

- Typical Range Limits
  - Azimuths: 90-160 degrees
  - Inclinations: 38-60 degrees

- Class of Vehicles Supported
  - Suborbital
  - Small Orbital (ELVs carrying payloads up to ~12,000 lbs.)
  - Experimental

- Nature of projects
  - NASA (Science, Technology, Education)
  - DoD (R&D, Targets)
  - Commercial

Current Capabilities

NASA Kennedy Space Center

KSC Space Shuttle Infrastructure

John F. Kennedy Space Center

Facilities

Vehicle Assembly Building	8 Acre Footprint, 525' Tall
3 Orbiter Processing Facilities	30,000 SF Each
Launch Pads A&B	Fuel/Oxidizer Tank Capacity of 1.8 M Gal
Shuttle Landing Facility	15,000' Runway, 300' Wide
Operations Support Building	200,000 SF 1378 Ofc Space
Operations Support Building 2	189,000 SF 860 Office Space
Launch Control Center	230,000 SF 237 Office Space
4 LPS Control rooms	
Logistics Facility	3-story, 230,000 SF

Facilities

NASA Shuttle Logistics Depot	8 bldg complex (Cape Canaveral)
Thermal Protection System Facility	2-story , 44,500 SF
Rotation Processing and Storage (RPSF) Facility	
PCC Facility	94,000 SF 235 Office Space
Launch Equipment Shop	On-site machine shop
Assembly and Refurbishment Facility	Managed by MSFC
Main Engine Processing Facility	
Hypergolic Maintenance Facility	
Parachute Refurbishment Facility	Managed by Marshall
Hangar AF	SRB/RSRM disassembly facilities
Hangar N & S	

KSC Space Shuttle Infrastructure

John F. Kennedy Space Center

- Support

- 300 Generators, 60 UPS Units, 156 Substations
- 30,000 Tons of Air Conditioning
- 40 Cranes, 183 Hoists, and 52 Elevators
- 500,000 Feet of Water Distribution Lines
- 440 Pieces of Heavy Equipment
- Over 170 Miles of Fiber Optic Cable
- Over 900 Fiber Optic Transmitters and 900 Fiber Optic Receivers
- LC-39 TV System Includes 166 Cameras, 9 Video Recorders, and Over
- 7770 Monitors
- 142,000 Items in Inventory
- 8,000 Issues Per Month

- Shuttle program funded facilities with current replacement value (CRV) >$1M is roughly $2.1B
- 50% of KSC real property with CRV of >$1M is dedicated Shuttle program or about $2.1B out of total $4.0B

Payload Processing

John F. Kennedy Space Center

Space Station Processing Facility (SSPF)

ISS elements are processed primarily in the 522,313 SF building

Additional Facility Capabilities:

O&C – Clean room warehouse mode

Supply Warehouse #1 – Shared facility provides warehouse storage for Flight Spares

Supply Warehouse #2 – Warehouse storage for Flight Spares, GSE, facility support spares

Aerospace Technician Shop

GSE Storage Facility

Vapor Containment Facility (VCF)

Additional Facility Capabilities:

Heavy Equipment Storage

Facilities O&M Building – Housing of Facility Technicians

Storage Building

Payload Support Building – Warehouse storage for Flight Spares, GSE, facility support spares

Apollo – Warehouse storage for bulk GSE

POL Shed – Provides paint, oil and lubricant storage

Payload Processing

John F. Kennedy Space Center

Payload Hazardous Servicing Facility (PHSF) - Processing of unique LSP payloads

Multi-Operations Servicing Facility (MOSB) - Administrative office space

Multi-Payload Processing Facility (MPPF) - Payload processing capability

<u>Additional Facility Capabilities</u>:

E&O (CCAFS) – Administrative office space

Hanger AE – Houses the LSP telemetry laboratory

RTG Facility – Provides capability to process special nuclear materials

Operation & Control (O&C) - Administrative office space for LSP personnel

Delta II Launch Pad

NASA Facilities at VAFB

John F. Kennedy Space Center

Vandenberg

VLS Hazardous Processing – Class 100K Payload Processing Facility

SLC-2 Remote Launch Control Center (VLS)

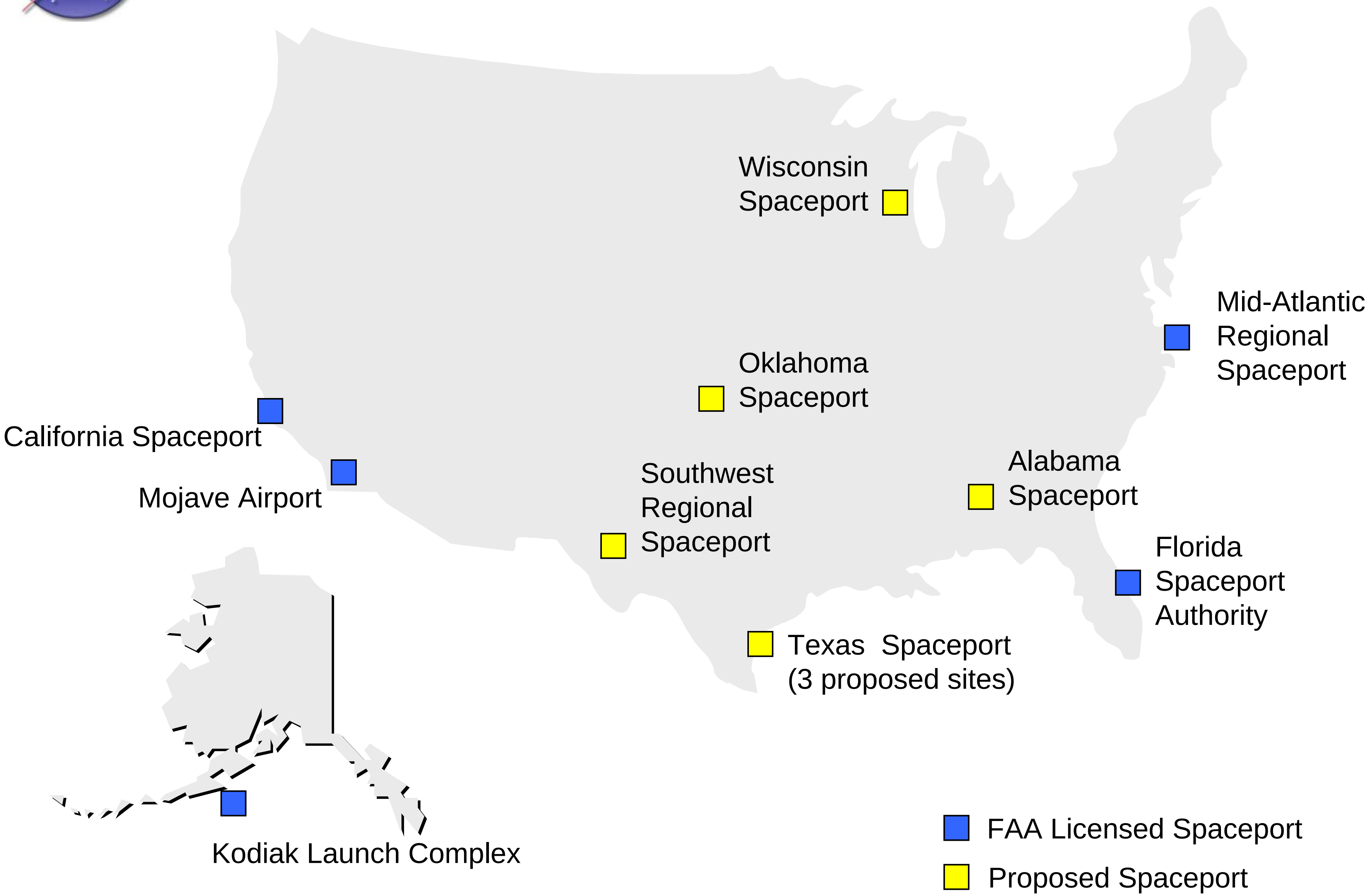
NASA VLS S/C – Mission Directors Center

NASA VLS S/C – Mission Directors Center

Current Capabilities

FAA Licensed Spaceports

Commercial Spaceports



Commercial Spaceports

- To date, approx. $165M has been invested into non-federal spaceports across the nation
- Primary investment funding is from State-level with some support from private and federal sponsorship.
- Contains infrastructure for processing a payload and commercial launch
  - Launch Pads and Runways
  - Infrastructure
  - Equipment
  - Propellants

Active Commercial Spaceports

- **Kodiak Launch Complex at Narrow Cape on Alaska's Kodiak Island, licensed in 1998**
  - LV and Payload Processing
    - Currently configured for Solid propellant launch
  - Total of 7 launches to date
- **California Spaceport, co-located at VAFB , licensed in 1996**
  - LV and Payload Processing
    - Currently configured for Solid propellant launch
      - Two Minotaur launches to date
    - Plans in-place to support liquid-fueled vehicle configurations
  - Launch azimuths ranging from 220° to 160°
- **Florida Spaceport Authority, co-located at Cape Canaveral Air Force Station, licensed in 1997**
  - Owns and Operates RLV Hanger at KSC and SLC-46, among others
    - Currently configured for Solid propellant launch
      - Two Athena launches to date
      - Supports suborbital launches for academic and research
  - Launch azimuths ranging from 47° to 110°
- **Mid-Atlantic Regional Spaceport, co-located at Wallops Flight Facility , licensed in 1997**
  - LV and Payload Processing
    - Currently configured for Solid propellant launch
    - Pad 0-A – built for Conestoga LV
    - Pad 0-B – Universal Launch Pad
  - Plans in-place to support liquid-fueled vehicle configurations
- **Mojave Airport, licensed in 2004**
  - Three runways
  - Supports horizontally launched sub-orbital RLVs
  - Total of five launches to date

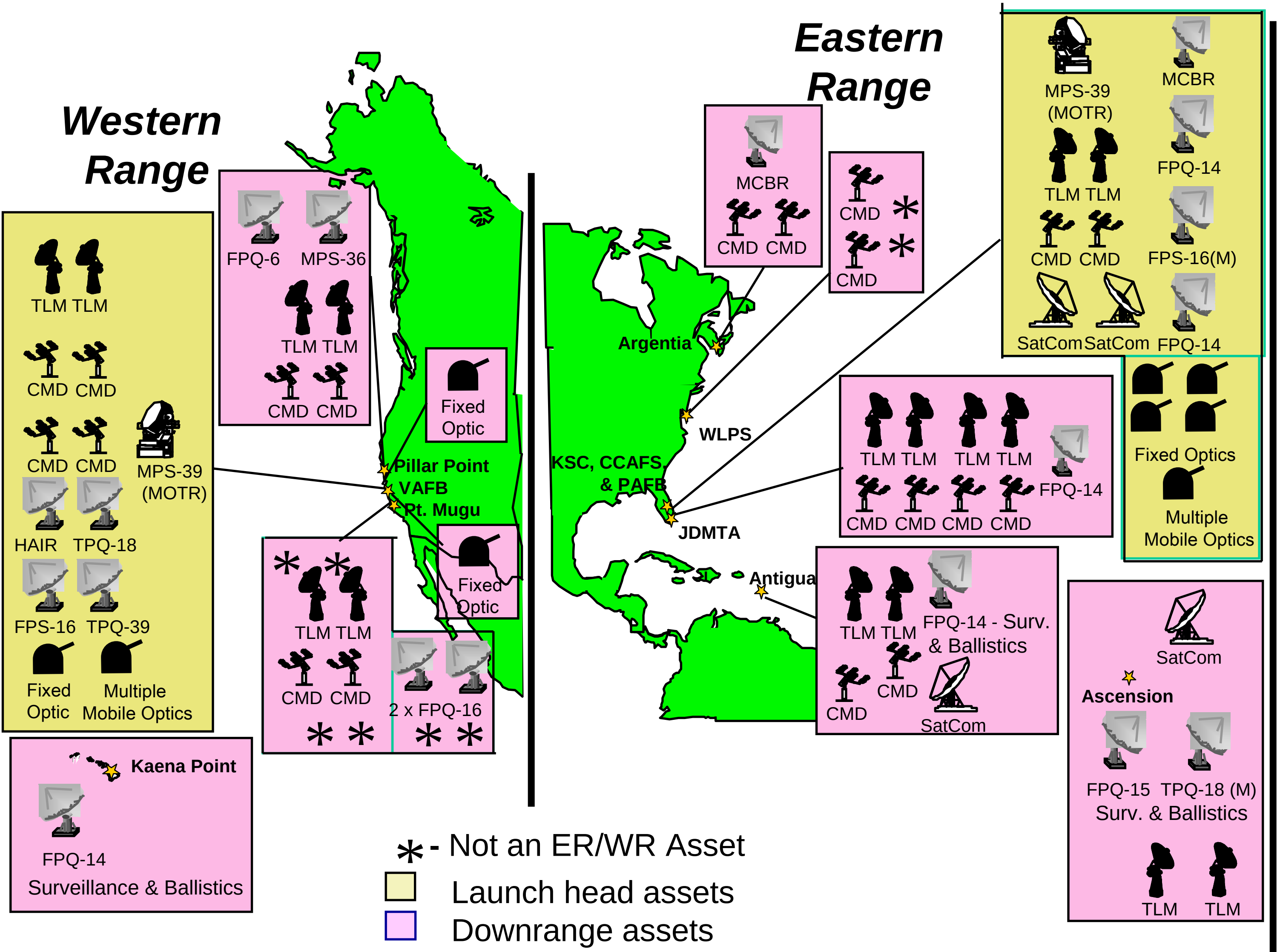
Potential Commercial Spaceports

- **Developing Spaceports**
  - **Southwest Regional Spaceport in Upham, NM**
    - Planned facilities: multiple launch complexes, runway, aviation complex, payload assy complex, cryogenic fuel plant
  - **Oklahoma Spaceport in Burns Flat, OK**
    - Current infrastructure: 13,500 runway, maint/repair hangars, rail spur
    - Planned service: support to horizontally-launched RLVs
  - **Wisconsin Spaceport**
    - Located on Lake Michigan
    - Have supported sounding rockets to altitude of 34mi
    - Host for Rockets for Schools
    - Seek to support orbital RLVs in the future
  - **Gulf Coast Regional Spaceport in Brazoria Co., Texas**
    - On-going safety analysis of different launch systems
    - Amateur Spaceflight Assn launched 12ft long rocket in 2003

- **Other Conceptual Spaceports**
  - Spaceport Alabama
  - South Texas Spaceport
  - West Texas Spaceport

Mixed Range Architecture

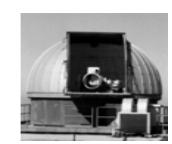
Current Launch and Test Range System Architecture



Typical Command Transmitter (6/10)*

Typical Tracking Radar (8/10)*

Typical S-band TLM Rcv Antenna (4/10)*



Typical Fixed Optic Site (3/4)*

Total # of Sites: 21/34*

* **(WR/ER totals)**

Range Instrumentation Architectures:
Fixed vs. Transportable vs. Space-Based

- Each architecture type has strengths, weaknesses, & optimal applications
  - Fixed/Ground-based:
    - Best suited for launch-heads & sites with continuous requirements
  - Mobile/Transportable:
    - Best suited to provide capabilities to limited use and/or mission unique launch sites (shared among multiple launch sites)
    - Provides gap-filling capabilities
  - Space-Based:
    - Best suited to provide down-range tracking & data, augmenting launch-head ground systems

- Ranges in the future are likely to use a combination of two or all three of these elements
  - Space-based data systems are expected to become a common feature of both established and emerging launch sites

Range Instrumentation Architectures:
Fixed/Ground-Based Instrumentation

- Fixed/Ground-based assets have traditionally been at the heart of the Range architecture
- Many Fixed/Ground-based assets have out-lived their intended design life and are expensive to replace/upgrade
- Due to the proven track record, Fixed/Ground-based assets will continue to compliment future Space-based architectures
- Typical Fixed/Ground-based assets include:
  - Down-Range Radar and Optical site
  - Communications antennae
  - Surveillance Radar at the Launch Site
  - Flight Control assets
  - Launch/Operations Control Centers

Range Instrumentation Architectures:
Space-Based Instrumentation

- Some space-based systems being fielded
  - GPS beginning to be used as a primary positional data source
  - TDRSS used for Space Shuttle
  - SATCOM for DoD applications

- Current federal technology developments expected to provide reliable, certified, & affordable space-based flight hardware within five years

- Space-based capabilities unlikely to fully replace launch-head ground systems
  - Data quality/latency & launch-area safety considerations pose constraints

- Implementing space-based flight hardware across the launch community would eliminate requirements for some existing down-range or deployed transportable instrumentation
  - Reduces fixed costs to Range-owners (costs passed on to customers)
  - Increases range responsiveness by eliminating time to deploy transportable systems

Range Instrumentation Architectures:
Mobile/Transportable Instrumentation

- Transportable ground-based capabilities are becoming increasingly attractive to space-launch community
  - Current state of technology enables instrumentation to be packaged in transportable containers
  - Provides ability to launch at non-established launch sites
  - Allows one set of instrumentation to support multiple locations

- National transportable range capabilities currently exist to provide full suite of traditional services required of space-launch missions, but…

- Significant opportunities remain to optimize designs to reduce quantity & size of containers, number of personnel deployed to the remote site, & increase capabilities
  - Developments offer reduced costs & improved responsiveness

Wallops Flight Facility Mobile Range Lessons Learned

- Mobile campaigns are not cheap! Logistics and personnel TDY costs can dominate traditional service costs
- Mobile campaigns do not afford the same level of service or redundancy as established ranges
- Remote sites often do not have needed reliable local services (telecommunications, power) adding cost, time, and risk to missions
- Much local coordination is needed for campaigns (air traffic, environmental, community interest)
- Mobile range equipment and personnel must be exercised regularly to be proficient
- Various organizations possess mobile range components, but few have full range capabilities
- Significant opportunities exist to improve the effectiveness of mobile range capabilities

Mobile Campaign Configuration for ELVs

<u>Launch Site</u>

- 1 - Mobile RCC w/command transmitters ***(6 personnel)***
- 1 – C-band radar system ***(2 personnel)***
- 1 – Telemetry van + 2 telemetry antennas ***(3 personnel)***
- 1 – Tracking camera ***(1 personnel)***
- 1 – Power generator system ***(1 personnel)***
- 1 – Fire console system ***(1 personnel)***
- 1 – Timing system ***(1 personnel)***
- 1- I&T Support Testing ***(2-3 personnel)***

<u>Downrange Site</u>

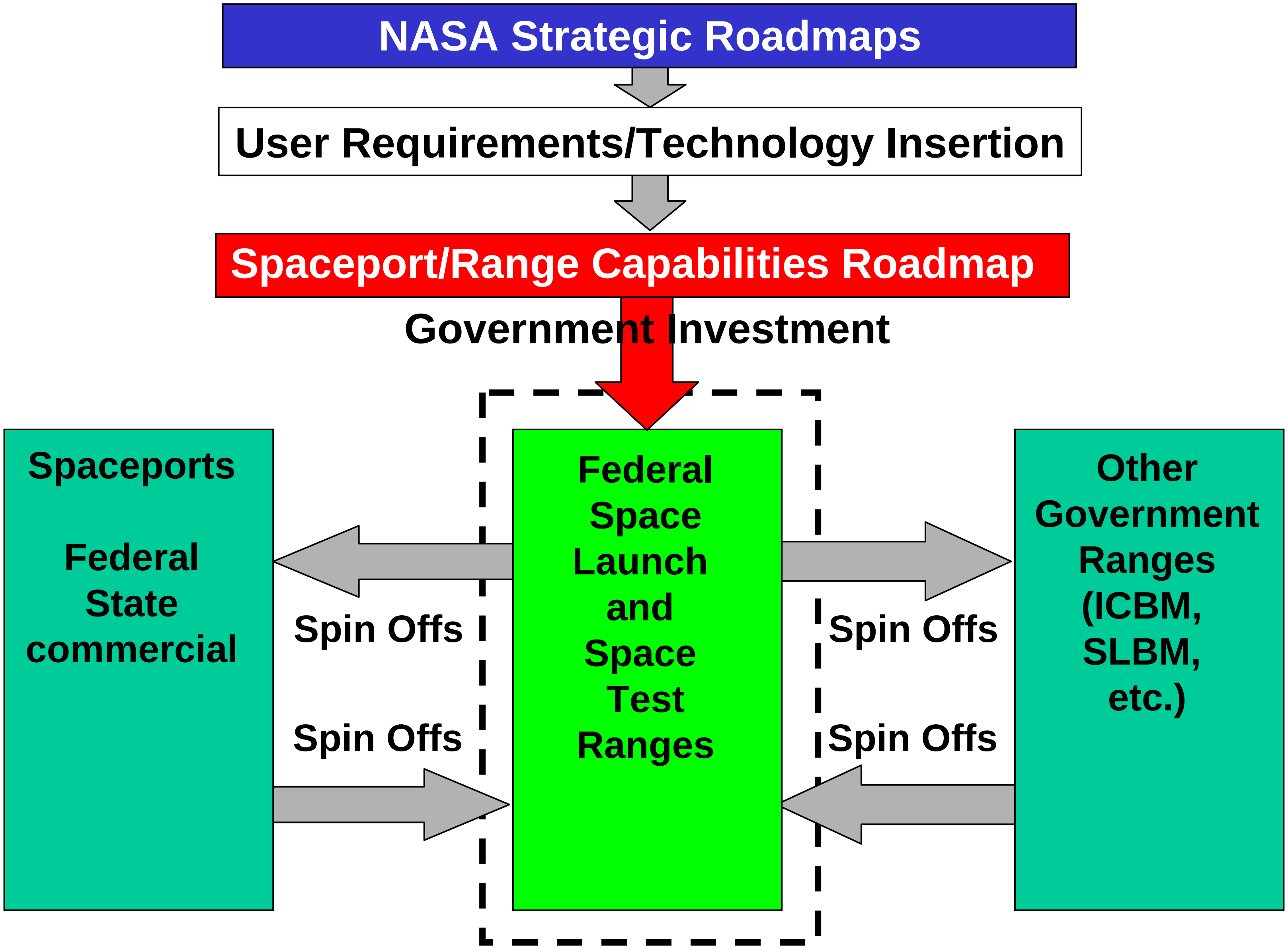
- 1 – Transmitter system ***(2 personnel)***
- 1 – C-band radar system ***(3 personnel)***
- 1 – Telemetry van + 1 telemetry antenna ***(2 personnel)***
- 1 – Power generator system ***(1 personnel)***

Note: ***(1) More than 1 downrange site may be needed for ELV missions***
(2) Requires personnel to carry out multiple functions (e.g., comm., PAO)

Requirements Focus

Explanation of Approach

Capabilities Roadmap Focus



Who Did We Talk To?

- USAF Ranges
- USAF Range Safety
- NASA Wallops Flight Facility
- NASA Mobile Range Assets
- FAA Licensing Office - Commercial Spaceports
- ARTWG/ASTWG/FIRST
- NASA Space Communications Office
- NASA Assessment of Emerging Space LV Range Needs
- Heritage Space LV Spaceport/Range Users – Boeing, LMCO, and Orbital
- NASA Spacecraft Spaceport/Range User
- MDA Range Users
- Navy Range Users
- NRO/Office of Space Launch

Team Assumptions

- Most Space Exploration activities assumed to require launch and processing support from federal facilities in Florida for CEV, heavy lift and intermediate and large class launch requirements
- Space Exploration requirements for the ranges involve:
  - Responsiveness (rapid turnaround) from tests, rehearsals or launches
  - Elimination of operational constraints imposed by Range such as launch azimuths and safety restrictions
  - Improved operational planning capabilities and approvals to support new missions. These include modeling, dispersions, break up analysis, and nuclear power systems
- Anticipate the USAF will continue to provide the basic capabilities for common user requirements and range/public safety at Eastern and Western Ranges for the foreseeable future
  - Includes scheduling, analyses, optics, telemetry, and communications
- Assume NASA will continue to provide spaceport customer services and institutional support at KSC and Wallops Flight Facility

Common Themes:2005-2015

- Public Safety
  - Simplify safety requirements for data and approvals
  - Real time weather support for all test and operations
  - Striking right balance between ground, mobile and space based assets
  - Enhanced flight termination systems and addition of satellite based assets for range tracking and telemetry
  - Improved air and sea surveillance
  - Improved mobile and transportable range assets
- Customer Services
  - Improvements in range turnaround for tests and operations
  - Higher volumes of data (i.e., continuous high-data rate communications)
  - Expanded and reserved frequencies for range operations
  - Improved digital equipment to support higher data rates
  - Improved scheduling and planning capabilities
  - Coordination of site enhancements impacts on users…PRIOR to implementation
  - Improved foreign national access and clearance
  - Lower cost of Launch Site/Range Operations

Common Themes:2016-2030

- Public Safety
  - Improved modeling for range safety(eg blast, toxic, re-entry)
  - Continuous Improvements in weather modeling and forecasting
  - Addition of IV&V for safety models
  - Expanded launch trajectories and azimuths
  - Enhanced capabilities for nuclear processing and storage

- Customer Satisfaction
  - Robust infrastructure for radars, optics and support equipment
  - Ability to conduct multiple parallel tests and operations
  - Increased launch window availability
  - Protect the availability of launch property at the launch head

Emerging Launch Vehicle Potential Spaceport/Range Needs

- **New emerging LV capabilities (e.g., DARPA FALCON, Space-X Falcon, Kistler) are intended to be low-cost access-to-space**
  - Generally smaller operations than heritage medium/heavy class LVs
  - Launch site operations and Range costs are larger percentage of overall service costs emerging companies are more sensitive to Spaceport/Range costs
  - Seek new technologies/capabilities to lower launch costs
    - Low Cost TDRSS Transceiver
    - Advanced Range Simulation
    - Mobile Fueling
    - Improved Surveillance

- **The emerging LV capabilities vary immensely in approach (e.g., liquid propulsion, solid rocket propulsion, air launch, etc.), which drives wide-range of needs at Spaceport/Range**
  - Spaceport:
    - Concrete Pad – “clean” pad
    - Lighting/Power
    - Access to site for transportable infrastructure
    - “Safe Crew” launch control area (bunker) or LCC
    - Payload encapsulation area
    - Portable assembly/stacking capability
  - Range
    - GPS/Range Tracking
    - Telemetry
    - Data and communications
    - Emergency vehicle support
    - Flight Trajectory assessment/range safety

Emerging Launch Vehicle Key Characteristics Range Considerations

Key Characteristic	DARPA FALCON Phase II A Contractors			
	Lockheed Martin Michoud	SPACE-X	Microcosm	Air Launch
Propulsion Concept	**Hybrid:** LOX/Rubber	**Liquid:** LOX/Kerosene	**Liquid:** LOX/Jet-A	**Liquid:** LOX/Propane
System Concept	Modular Simple vehicle and payload assembly and launch erection	Modular Simple vehicle and payload assembly and launch erection	Modular Simple vehicle and payload assembly and launch erection	Air drop & launch
Potential Launch Site	WFF	Kwajalein and/or Vandenberg	WFF	Any available/capable runways in the U.S., air launch from a C-17
Key Concept Of Operations	Simple Transporter/ Erector/Launcher Crane to erect full vehicle	Simple Transporter/ Erector/Launcher Crane to erect full vehicle.	Simple Transporter/ Erector/Launcher Crane to erect full vehicle plus extremely simple approach for all aspects of CONOPS	Drop launch from C-17 aircraft with simplified range tracking, safety, logistics & trajectory shaping and orbital mechanics

Emerging Launch Vehicles

Description of Potential Capability

- •Target small market to lift small payloads to LEO
- •1000 lb to 28.5 deg. Circular , 100 nm altitude
- •Target low recurring cost, less than$5M (20 launches/yr)
- •New launch operations/operationally responsive
  - •Reach alert status within 24 hours
  - • Launch within 24 hours
  - • Rapidly reconfigure launch systems to support higher launch tempo in a short time interval
- • Improved weather modeling, simulation, analysis, and prediction to reduce operations down time
- • Seek low cost vehicle processing infrastructure for new low cost launch vehicle

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Launch infrastructure and systems for new low cost small launch vehicles	U/R	U/R	Successful completion of development and first flight
a) Rapid turnaround of launch infrastructure b) Limited automated capability currently available for tracking, range safety & FTS	U/R	U/R	a) Increase processing speed, increase flexibility, decrease mission reconfiguration time b) Reduce cost associated with mission support
Weather Modeling Improved prediction capability to reduce false alarms	U/R	U/R	Reduce operations down time due to weather restrictions by a factor of 2

Current Capability

- • ICBM and Pegasus class launches range from $20-30M and assume low flight rates
- •Limited low cost/rapid turnaround, fully automated range capabilities currently available
- • Launch processing systems and pads are specific to launch vehicles based on larger heritage systems
- • Limited experience with launch mission manifests for rapid turnaround capability

Mission/Strategic Drivers

- • Multiple low-cost SLV's project readiness in 2008-2009
- •Targeted users: national security, civil, commercial, education, Amateurs (OSCAR satellites , etc.) low cost new technology demonstrations in-space
- •Potential low-cost approaches could be applied to future spiral(s) (10Klb or greater capability)

Manifest Considerations

Combined DOD, Current NASA, and Space Exploration Projections

NASA Launch Requirements

SCIENCE

- Robotic
  - Planetary Landers
  - Planetary Orbiters
  - Deep Space
  - Earth Observing
  - Sun-Earth Connection
  - Astrophysics
- Observatories

OPERATIONS

- ISS Crew
- ISS Assembly
- ISS Cargo
- ISS Partner Assets
- Space Communication
- Education payloads
- Reimbursable customers
- CEV Operations

SPACE EXPLORATION

- Robotic Precursors
- Technology Demonstrators
- Crew Exploration Vehicle(s)
- Project Prometheus
  - JIMO
- Moon/Mars cargo

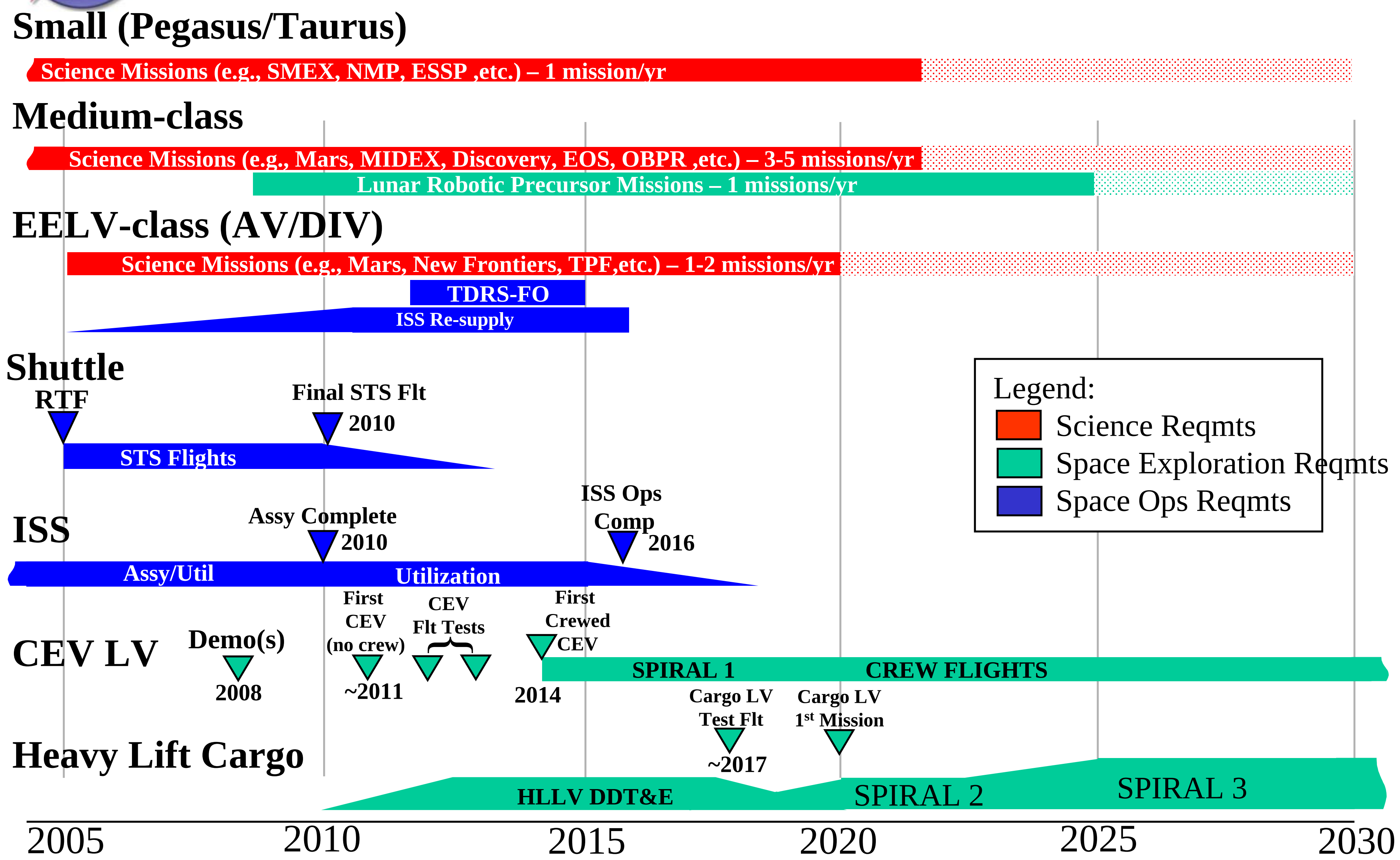
Access Considerations

- One of a kind science
- Nuclear propulsion
- Sensitive instruments
- Unique orbits
- Constrained launch periods
- Instantaneous launch windows

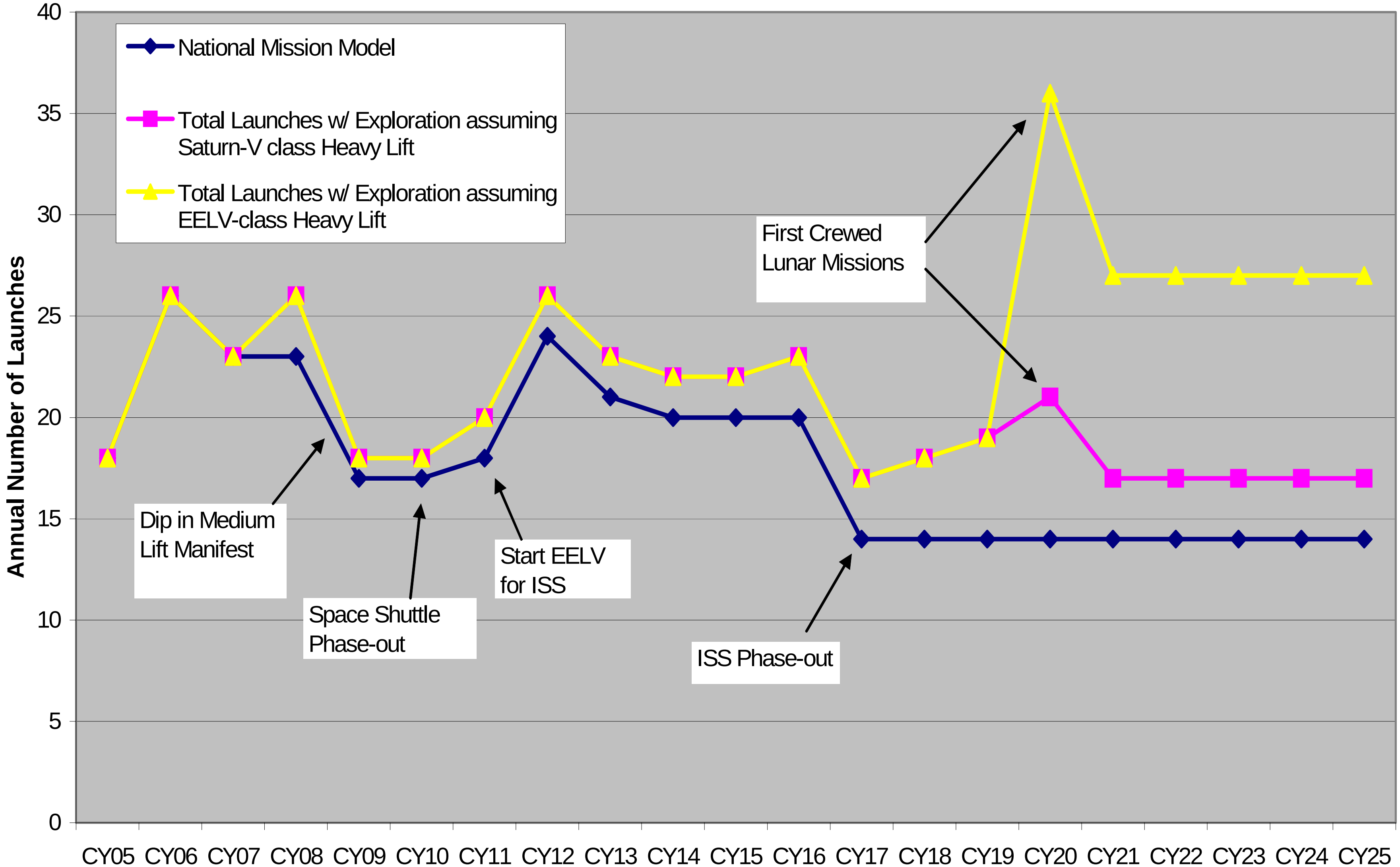
- Crew safety and health
- Crew logistics (food/water)
- Pressurized up and down mass
- Automated rendezvous & docking
- Moon/Mars operations

- Crew safety and health
- Crew logistics
- Automated rendezvous & docking?
- In space operations/assembly?
- Nuclear propulsion
- System of system approach

NASA Launch Requirements



Manifest Projections



Note: Totals above do not include emerging launch capabilities/market, nor does it include the missile-related T&E activities

Manifest Considerations

- NASA continues to pursue a Mixed Fleet Launch Strategy
  - Launch Services
    - Steady requirement for Small and Medium-class services projected
    - Modest use of Intermediate and large class (EELV)services
  - Space Shuttle
    - Complete ISS Assembly and retire Space Shuttle by end of 2010
  - International Launch Capability
    - Utilize foreign partner launch capability for international cooperatives
  - ISS cargo services, CEV and heavy lift requirements under review
    - Space Shuttle-derived, EELV-derived vehicle or new system in trade space

- DoD focus to consolidate all space payloads to EELV
  - Continue phase out of heritage systems
    - Titan IV targeted for end of 2005, Delta II targted for 2007/2008
  - Invest in sustainment of two EELV suppliers thru at least 2009
  - Meet small class requirement through use of refurbished ICBM assets

- DARPA FALCON Program offers potential for DOD operationally responsive lift needs and NASA science, education, technology needs

Manifests Considerations (continued)

- Space Exploration Heavy Lift Requirements
  - New Heavy Lift capability first use ~ 2016 timeframe
  - How much performance capability is required per flight?
    - Drives number and frequency of launches needed per planetary window
    - Drives In-space complexity
    - Launch System requirements may vary/evolve through Spiral development
  - Relationship between CEV and heavy vehicle is under review

- Unique Payload Processing Infrastructure Requirements
  - Facilities may need to be compatible with Nuclear power sources/propulsion
  - Oversized Spacecraft may require unique facilities
  - Unique transportation needs may exist
  - Seek synergy with TBD requirements with larger government user community

Manifest Considerations (continued)

- Continue to assess effects of a stagnant commercial market for foreseeable future
  - Domestic launch providers offering foreign services to obtain some market share
- New emerging launch capabilities and market continues to be unpredictable, hence affects on Roadmap have been to acknowledge and note
- Missile defense test and evaluation activities are not included in this assessment
- Flight rate and range testing volume do not pose an immediate concern as they fall within historical experience , need to monitor closely any potential increases in post 2015 timeframe as Space Exploration activities ramp up
- Expect that Space Exploration likely to dictate some requirements that drive transformational change, such as new human-rated systems and multi-launch scenarios in short duration planetary science window

Capability Breakdown Structure

Critical Capabilities Investment

<u>Now through 2015</u>

SPACEPORT AND CUSTOMER SERVICES:

1. Communications, command and control for Constellation
2. Improved commodities servicing next generation Personal Protective Equipment (PPE) (e.g. Advanced SCAPE)
3. Pad crew access
4. Human-related systems checkout and servicing
5. Egress and emergency systems
6. Launch infrastructure and systems for new vehicles
7. Rapid turnaround of launch infrastructure
8. Weather modeling for increased resolution and improved prediction capability

RANGE AND PUBLIC SAFETY:

1. Improved metric tracking for ground systems
2. Enhanced flight termination system
3. Improved broadband communications system
4. Space-based telemetry and range safety
5. Readily deployable mobile range assets
6. Improved surveillance for sea traffic in launch impact zone

INSTITUTIONAL:

1. Service based communications
2. Consolidation of communication systems
3. Data access & security

<u>2015 and beyond</u>

SPACEPORT AND CUSTOMER SERVICES:

1. Nuclear power and propulsion processing
2. Abort recovery operations for nuclear power and propulsion systems

RANGE AND PUBLIC SAFETY:

(Decisions for additional capabilities needed to meet future requirements are TBD)

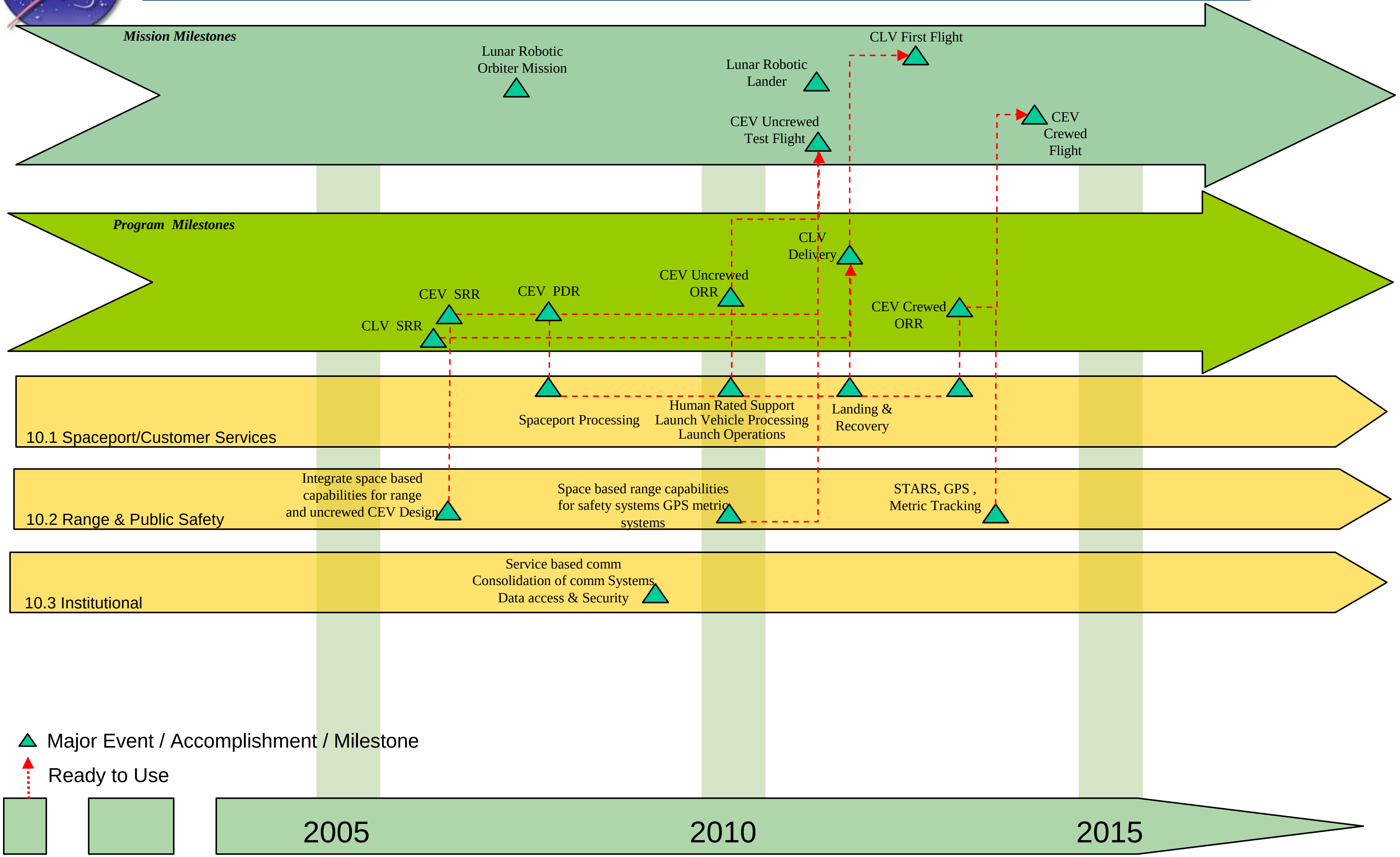
INSTITUTIONAL:

(Decisions for additional capabilities needed to meet future requirements are TBD)

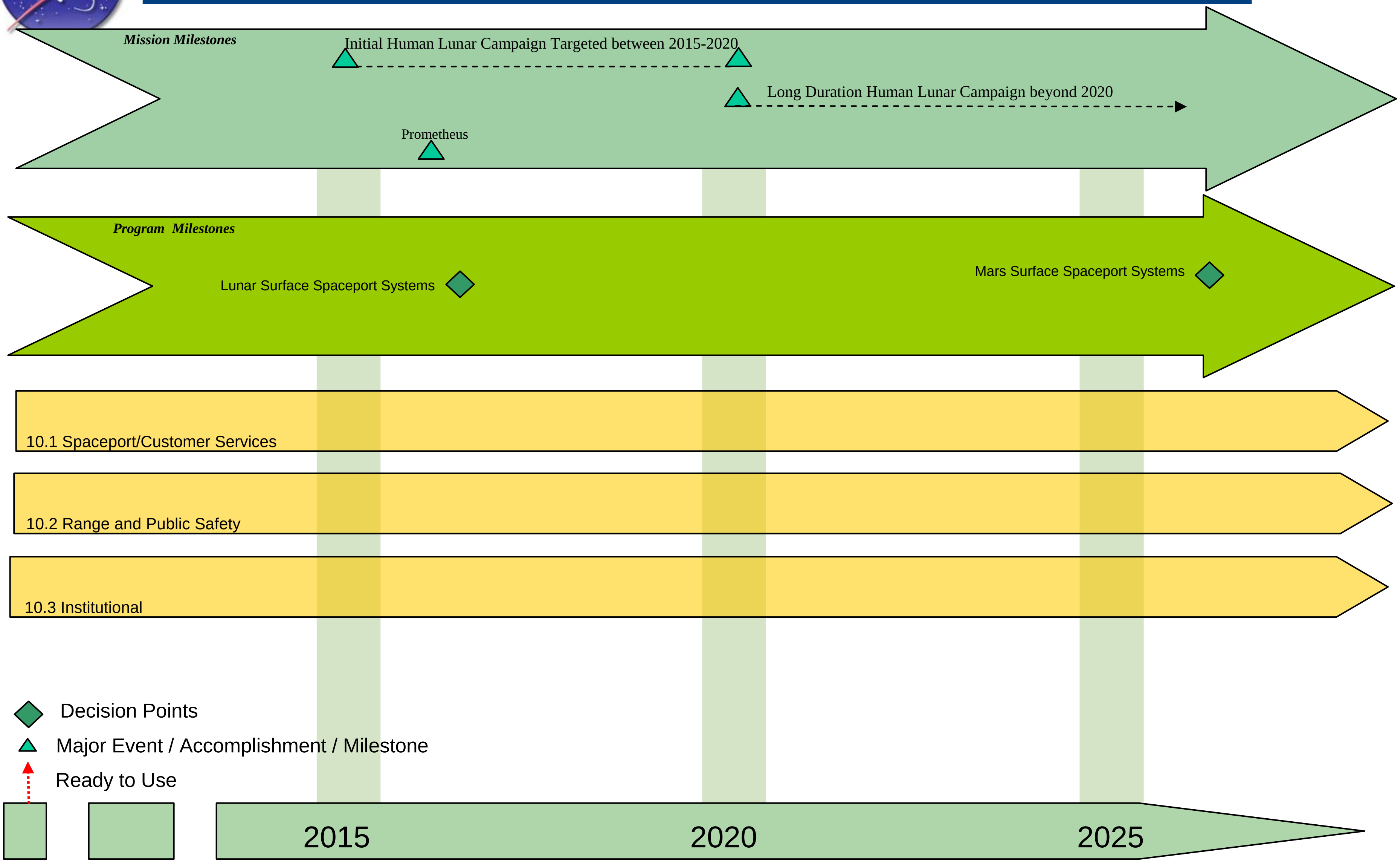
Capability Breakdown Structure

- Transformational Spaceport & Range 10
  - Spaceport and Customer Services 10.1
    - Spacecraft Processing 10.1.1
    - Human Rated Support 10.1.2
    - Launch Vehicle Processing 10.1.3
    - Launch Operations 10.1.4
    - Landing & Recovery 10.1.5
  - Range and Public Safety 10.2
    - Ground Based 10.2.1
    - Space Based 10.2.2
    - Mobile Based 10.2.3
  - Institutional 10.3
    - Planning & Scheduling 10.3.1
    - Ground Safety 10.3.2
    - Enabling Services 10.3.3
    - Communications 10.3.4
    - Weather 10.3.5
    - Command & Control 10.3.6
    - Infrastructure Sustaining/Improvements 10.3.7

Transformational Spaceport & Range Roadmap Timeframe < 2015



Transformational Spaceport & Range Roadmap Timeframe > 2015



Capabilities Assessment Quad Charts

Description of Potential Capability

- Provides a general description of potential capabilities to meet future needs derived from postulated requirements in lieu of real requirements

Preliminary Gap Assessment

- Provides examples of individual capabilities
  - Preliminary assessment by KSC of the APIO Capability Readiness Levels (CRL)
  - Preliminary assessment of standard Technology Readiness Levels by ARTWG/ASTWG
  - KSC-proposed performance metrics
- Requires further analysis for link with still emerging Space Exploration priorities/requirements

Current Capability

- Provides general description of current capabilities, if applicable, and/or gap for the future

Mission/Strategic Drivers

- Identified Program Milestones

10.1.1 Spacecraft Processing

Description of Potential Capability

- Receive, test, service, integrate, and transport crewed and uncrewed spacecraft elements and integrate them to the launch vehicle. Specific capabilities include:
  - Distributed communications, command & control system using standard hardware, software, and interfaces for flight elements at dispersed sites, and also including standardized test equipment
  - Improved commodity servicing, associated leak detection, and system operations verification for preflight, launch, landing and recovery operations, next generation PPE for hazardous commodities
  - The capability to store, secure, process and test nuclear power and propulsion systems for flight hardware processing
  - Improved weather modeling, simulation, analysis, and prediction to reduce operations down time

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Communications, Command and Control for Constellation	2-3	5-8	Increase data volume and integration, decrease development and implementation costs. Increase speed and accuracy of fault detection and mitigation
Improved Commodities Servicing Next generation Personal Protective Equipment (e.g. Advanced SCAPE)	3-4	5-8	Improve standardization, decrease commodity loading times and improves safety and reliability
Nuclear Power and Propulsion Processing	2	5-8	Assure personnel and public safety, increase mission success Obtain required permits and certification
Weather Modeling a) Increase resolution of models (Space and Time) b) Improved prediction capability to reduce false alarms	4	a) 6 b) 4	a) With 500m resolution, initialize models with current weather data b) Reduce operations down time due to weather restrictions by a factor of 2

Current Capability

- Flight elements use different, individually tailored, communication, command, and control architectures throughout their life depending on their location (factory, launch site, in-space), and have unique interfaces for test, checkout, and servicing
- Hazardous commodity processing requires the use of manually operated equipment and SCAPE systems for personnel protection which are approaching the end of their useful life
- Experience with processing of nuclear power generation systems is limited to RTGs (no reactor experience or active conversion experience)

Mission/Strategic Drivers

- Communications, Command and Control systems available by uncrewed CEV ORR 2010
- Commodities Servicing systems available by uncrewed CEV ORR 2010
- The next generation personal protection equipment development must start as soon as possible to ensure replacement prior to end of useful life of current equipment
- Nuclear Power and Propulsion Processing systems available for Prometheus 2016
- Continuous improvements in weather modeling and forecasting
  - Increased launch window availability
  - Responsiveness (rapid turnaround) from tests, rehearsals and launches

10.1.2 Human Rated Support

Description of Potential Capability

- Provide crew support during launch operations, landing and recovery. Capabilities include :
  - Pad crew access capability to the spacecraft
  - Checkout and service specific systems supporting human rating e.g.: ECLSS; Air conditioning/revitalization; fuel cells; propulsion/attitude control; waste management; spacesuits; crew-related communication and data transmission.
  - Provide specific systems and capabilities for crew support and emergency egress and for abort/landing emergencies

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Pad Crew Access	5	9	Successful completion of design verification and operation readiness
Human-related systems checkout and servicing	5	9	Successful completion of design verification and operation readiness
Egress and Emergency systems	5	9	Successful completion of design verification and operation readiness

Current Capability

- Space Shuttle capabilities are planned to be phased-out in the 2010-2011 timeframe – TBD utilization for CEV
- Human rated vehicles require additional systems and ground support not required on non human rated pads
- Support to mission aborts or landing emergencies provided at multiple remote sites around the world.

Mission/Strategic Drivers

- Human-related systems available by crewed CEV ORR 2013
- Egress and Emergency systems available by crewed CEV ORR 2013
- Responsiveness (rapid turnaround) from tests, rehearsals or launches

10.1.3 Launch Vehicle Processing

Description of Potential Capability

- Vehicle processing infrastructure specific to any new advanced launch vehicle
- Rapidly reconfigure launch systems after a launch to support launch campaigns of many launches over a short period of time
- Improved weather modeling, simulation, analysis, and prediction to reduce operations down time
- Command & Control system compatible with 10.1.1

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Launch infrastructure and systems for new vehicles	1-2	8-9	Successful completion of readiness reviews
Rapid turnaround of launch infrastructure	1	5-7	Increase processing speed, increase flexibility, decrease mission reconfiguration time
Weather Modeling a) Increase resolution of models (Space and Time) b) Improved prediction capability to reduce false alarms	4	a) 6 b) 4	a) With 500m resolution, initialize models with current weather data b) Reduce operations down time due to weather restrictions by a factor of 2

Current Capability

- Launch processing systems and pads are specific to launch vehicles
- Limited experience with launch mission manifests for rapid turnaround capability
- Improved capability will reduce risk to schedule and mission assurance

Mission/Strategic Drivers

- Vehicle processing infrastructure specific to advanced launch vehicles must be verified operational prior to ORR for crewed CEV 2013
- Continuous improvements in weather modeling and forecasting

10.1.4 Launch Operations

Description of Potential Capability

- Improved systems, equipment and services for advanced launch vehicles and payloads
  - Next generation Personal Protective Equipment
- Improved weather modeling, simulation, analysis, and prediction for safer and less restrictive weather constraints
- Command & Control system compatible with 10.1.1

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Next generation Personal Protective Equipment	4	6	Decrease hazardous commodity servicing time, improve safety & reliability
Weather Modeling a) Increase resolution of models (Space and Time) b) Improved prediction capability to reduce false alarms	4	a) 6 b) 4	a) With 500m resolution, initialize models with current weather data b) Reduce necessary scrubs / delays due to weather restrictions by a factor of 2

Current Capabilities

- Existing Personal Protective Equipment for propellant loading are reaching the end of their useful life
- Improved capability will reduce risk of injury, loss of life and/or damage to flight hardware

Mission/Strategic Drivers

- The next generation personal protection equipment development must start as soon as possible to ensure replacement prior to end of useful life of current equipment
- Continuous improvements in weather modeling and forecasting
  - Increased launch window availability
  - Responsiveness (rapid turnaround) from tests, rehearsals and launches

10.1.5 Landing and Recovery

Description of Potential Capability

- Abort recovery operations for missions which include nuclear power and propulsion systems
- Recovery of crew after nominal mission and landing TBD depending on design
- Recovery of CEV and other spacecraft items TBD depending on design

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Provide nominal recovery for CEV uncrewed/crewed	4	7-8	Successful Completion of Crew Recovery and Vehicle safing Readiness Reviews
Abort recovery operations for nuclear power and propulsion systems	3	6-8	Public Safety

Current Capabilities

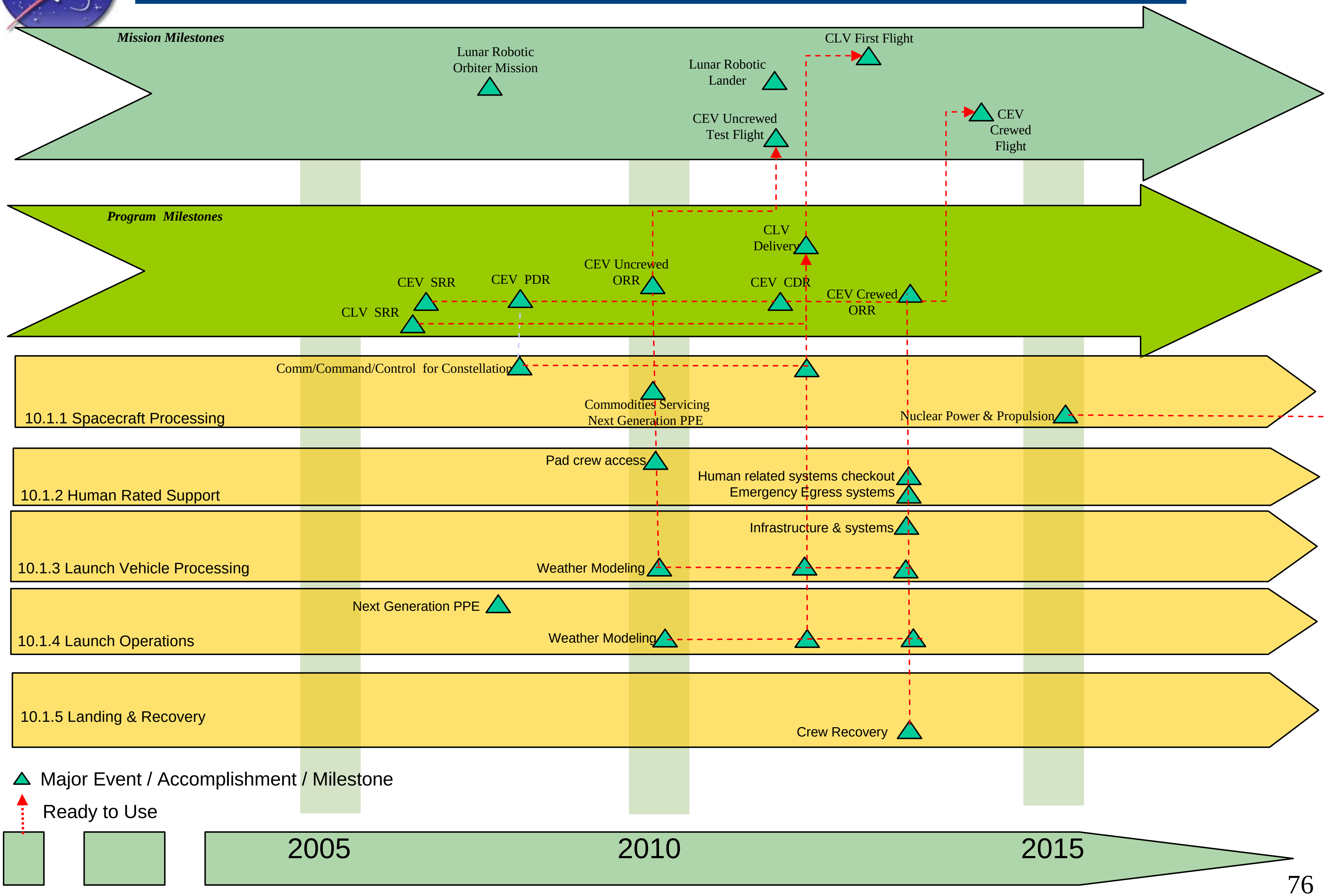
- Contingency plans to recover RTG
- Recovery of Orbiter (runway) and SRB's (ocean) for Shuttle missions
- Runway and turnaround Orbiter operations conducted at two prime sites plus several contingency and abort sites.
- Large amounts of support personnel and equipment at each landing site, and smaller (but significant) numbers of each at contingency and abort sites

Mission/Strategic Drivers

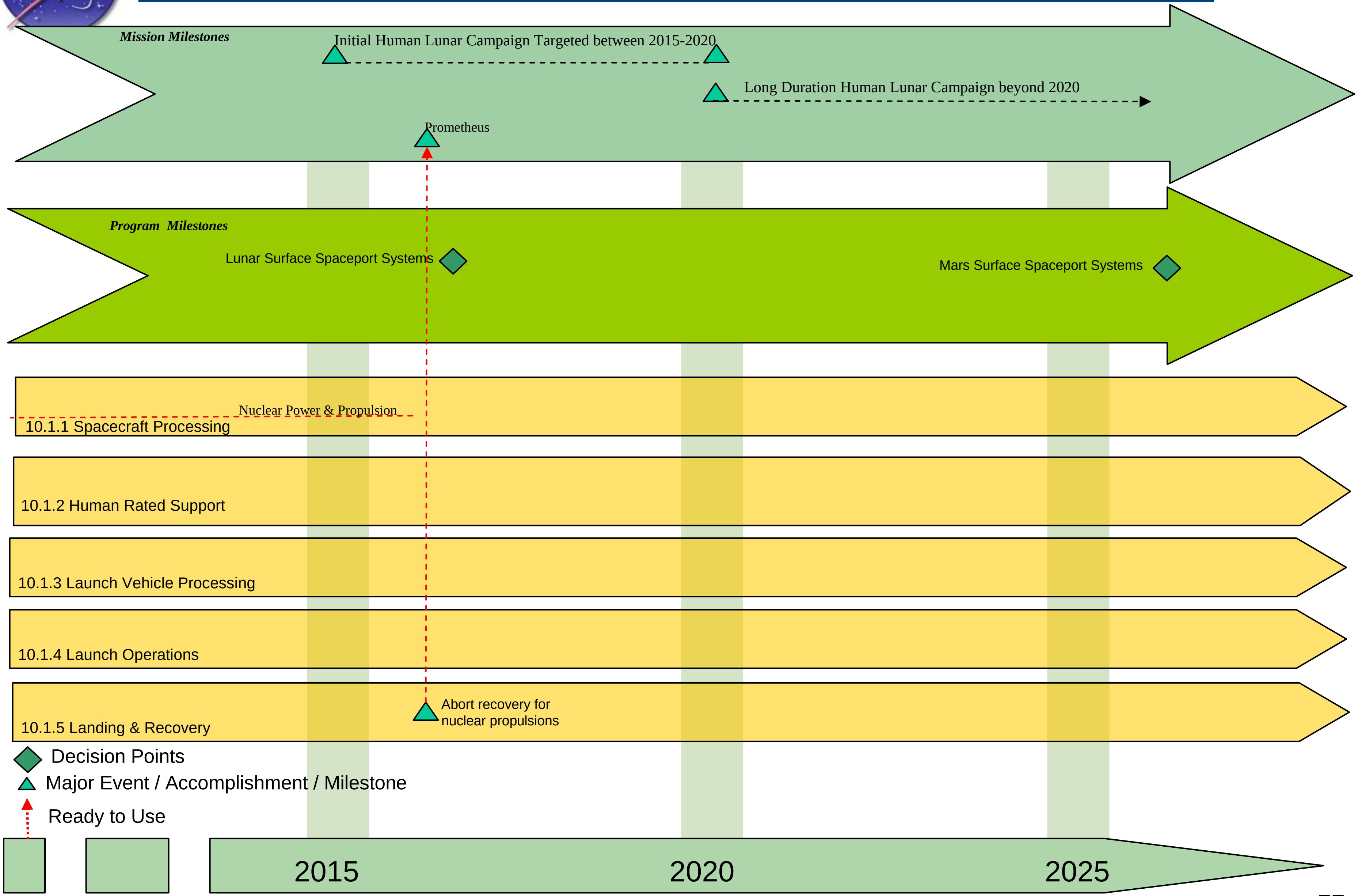
Potential Missions:

- Abort operation for nuclear power and propulsion for Prometheus 2016
- Recovery implementation planning for crewed CEV ORR 2013

10.1 Spaceport/Customer Services < 2015



10.1 Spaceport >2015



10.2.1 Ground-based

Description of Potential Capabilities

- Ground-based capabilities required:
  - Expand trajectories and azimuth improving metric tracking capabilities and continuous broadband communications from launch to orbital insertion

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Improved metric tracking for ground systems	3	6	Tracking accuracy and coverage

Current Capabilities

- Current system is fully functional for a limited set of launch azimuths and trajectories which relies on aging (1960s) technology and expensive ground-based assets
  - C-band radars
  - Optics
  - S-band telemetry
  - Flight termination system

Mission/Strategic Drivers

- Elimination of downrange C-band radars for metric tracking
- Space Exploration trajectories are TBD
- Responsiveness (rapid turnaround) from tests, rehearsals and launches

10.2.2 Space-based

Description of Potential Capabilities

- Enhanced flight termination system
- Provide continuous broadband communications from launch to orbital insertion
- GPS metric tracking to expand trajectories and azimuth
  - The Air Force is mandating GPS as the prime metric tracking solution

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
a) Enhanced flight termination system b) Improved communications e.g. Space-based Telemetry & Range Safety	5	6	Tracking pointing accuracy Instrumentation size and weight Data rates, data latency, bit error rate
Use of GPS for metric tracking	5	7	Tracking accuracy

Current Capabilities

- Limited use of space-based capabilities
  - TDRSS for communications
  - GPS for metric tracking is dependent on mobile or ground relays

Mission/Strategic Drivers

- 2006: Integrate space-based range capabilities with system requirements into uncrewed CLV design (CLV SRR)
- 2011: Support uncrewed CEV operation with space-based Telemetry

10.2.3 Mobile-based

Description of Potential Capabilities

- Readily deployable mobile range assets
- Augmentation of ground-based systems with an improved sensor suite on airborne or ship-based systems

Preliminary Gap Assessment

Capability	CRL	TRL	Metric
Readily deployable mobile range assets	6	7	Comparison with other range assets
Improved surveillance for air & sea traffic in launch impact zone	7	9	Integrated on board assets

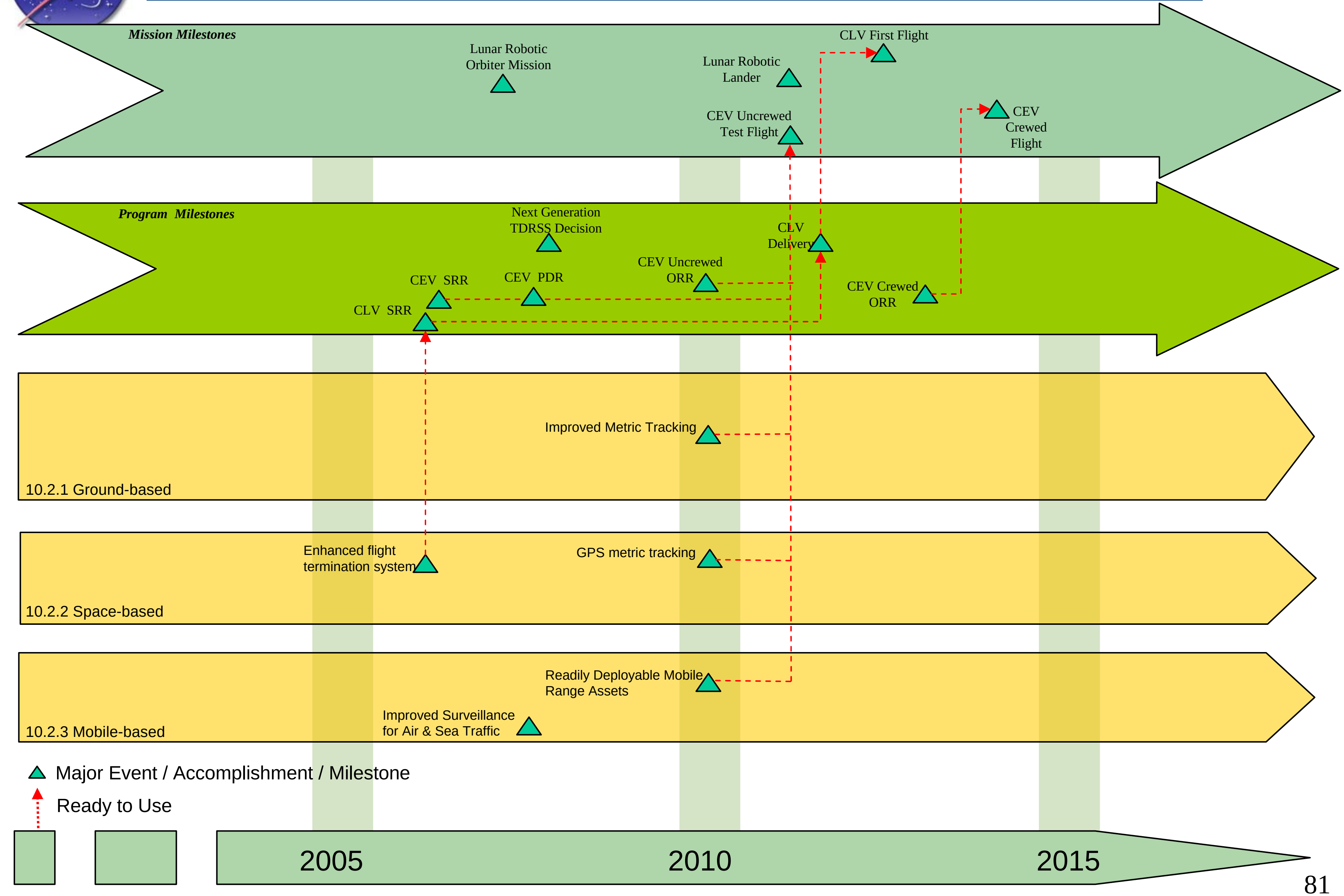
Current Capabilities

- Only a few mobile range assets (i.e., WFF, AFRL, WSTF). These are comprised of multiple trailers that need to be transported to remote sites at great difficulty, time, and expense
- Ground based systems augmented by a variety of airborne and ship-based systems

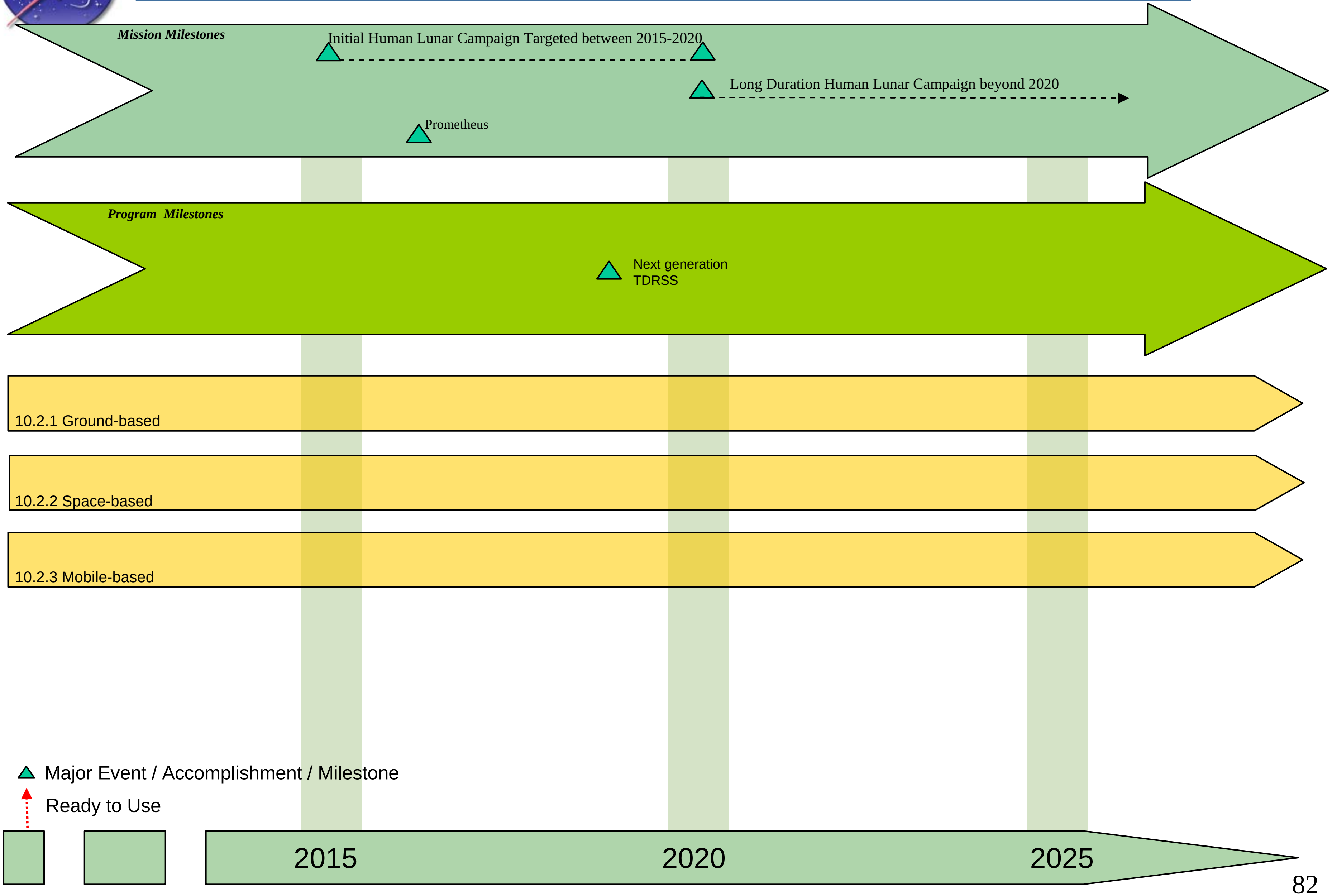
Mission/Strategic Drivers

- Provides improved ability to launch at non-established launch sites
- Improved public safety

10.2 Range and Public Safety < 2015



10.2 Range and Public Safety > 2015



10.3.4 Communications

Description of Potential Capabilities

- Transform from a system-based communications infrastructure to a service-based infrastructure; users subscribing to the network would receive user-specific service (access, permissions and functionality)
- Consolidation of communications infrastructure into a single carrier, maintaining compatibility with mission-specific communications
- Increase worldwide access to mission data while maintaining appropriate security

Preliminary Gap Assessment

Capabilities	CRL	TRL	Metric
Service-Based Communications a) Multi-vendor Volume	3	5	a) Provide on-demand comm. Coverage to authorized subscriber without dropouts b) Increase data rates 10x c) Automatic data collection and analysis services
Consolidated Communication Infrastructure a) Compatibility mission unique transition	3	6	Common protocols and media utilized for all comm. Systems
Data Access & Security a) Admin & Management	3	4	a) Web based access; encryptions and authentication of data b) QoS integrated info Mgmt of Global Information Grid

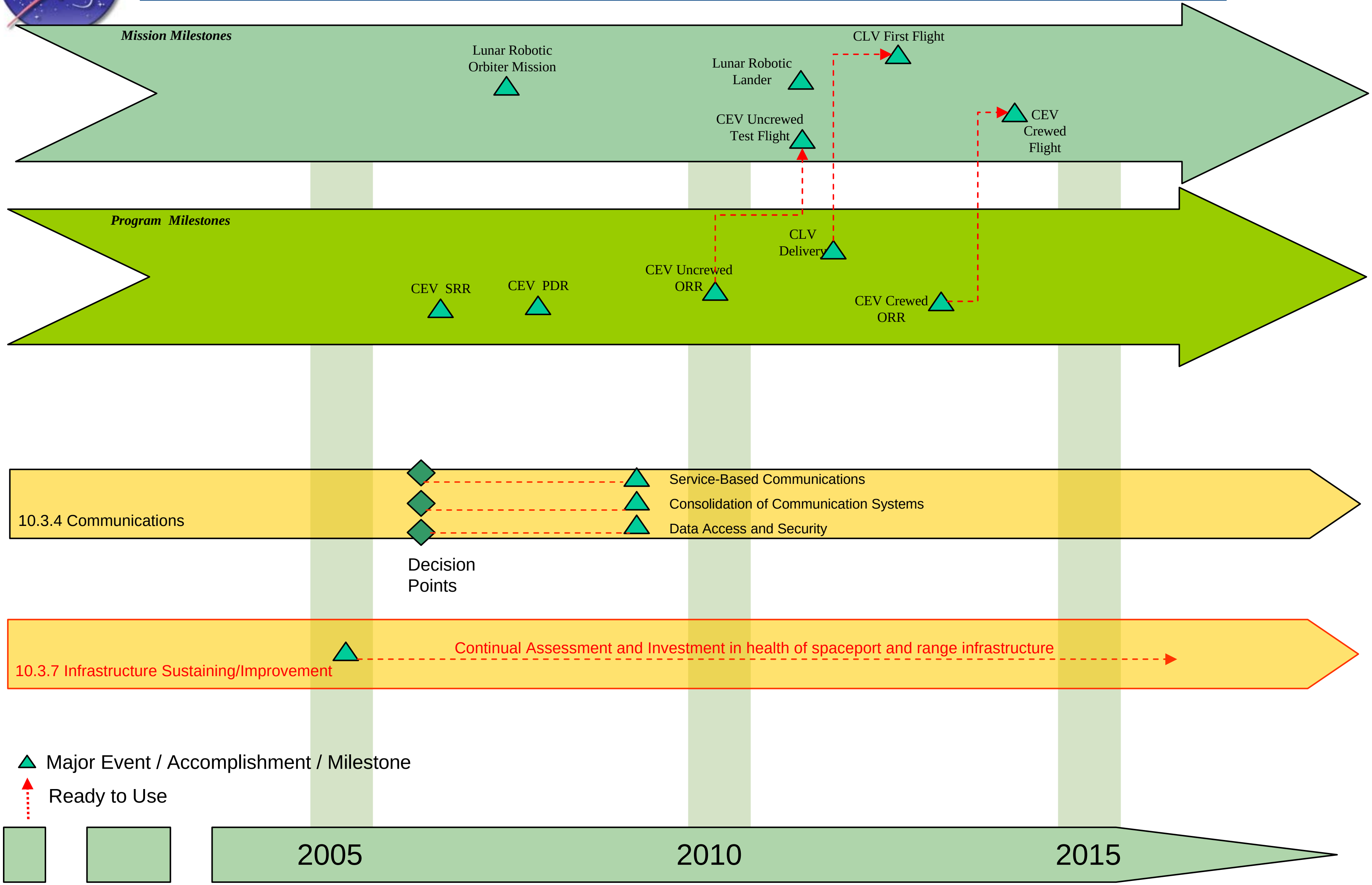
Current Capability

- All existing voice, video and data communication services are provisioned using dedicated systems, each with unique end instruments, cabling, distribution equipment, logistics spares, configuration management, and engineering. Separate unique systems required dedicated engineering, operations, system management and equipment spares resulting in increased costs
- Emerging communications technologies show promise that communications services can be provided from a common highly reliable, high bandwidth network capable of providing voice, video and data services. This approach significantly reduces the overall cost of designing, operating and maintaining communications capabilities while significantly increasing responsiveness and flexibility to the customer

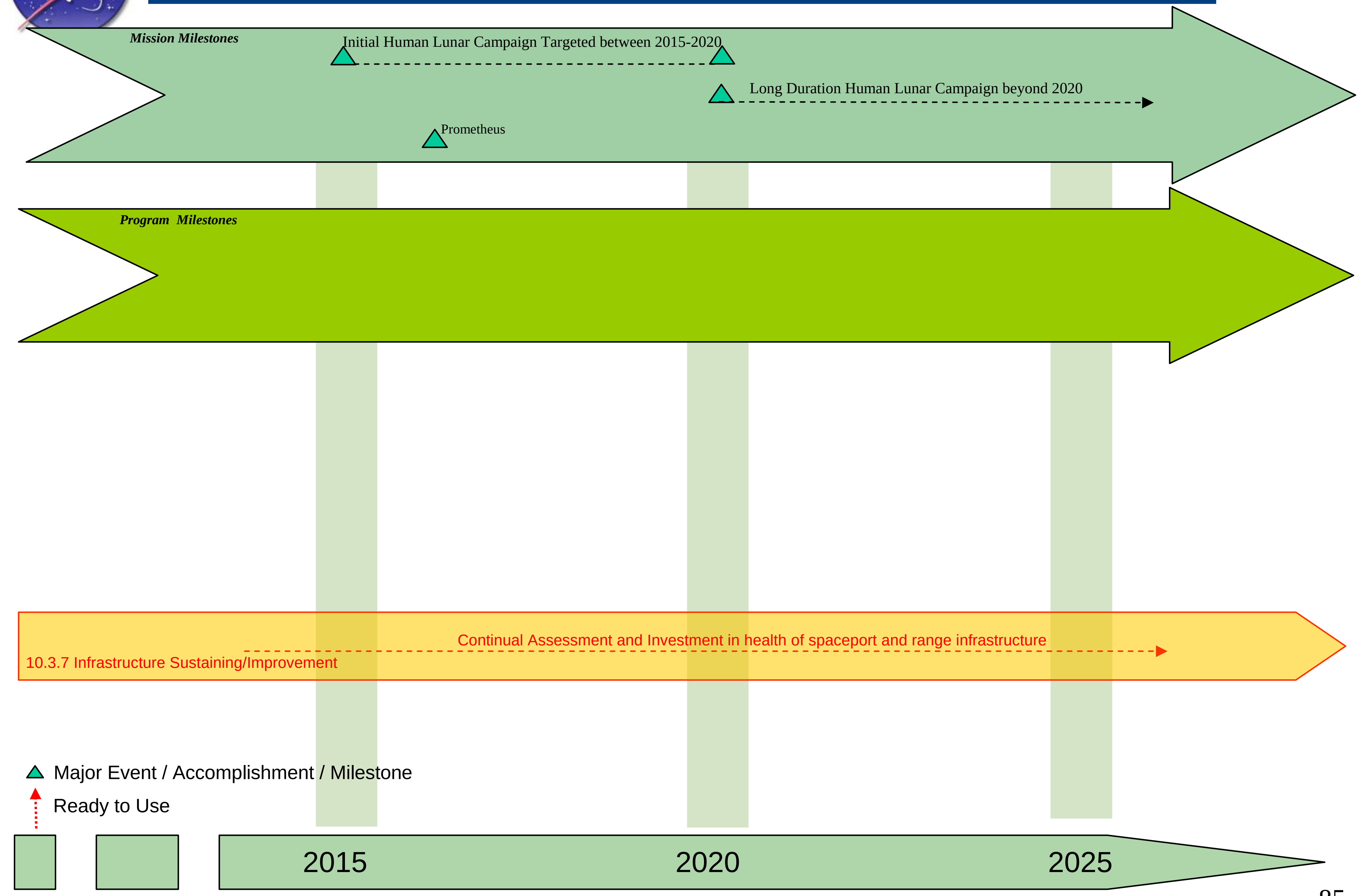
Mission/Strategic Drivers

- Improved services based communication infrastructure will allow rapid reconfiguration and provisioning of communications services to support element testing and daily operations at significantly reduced cost
- Provides high bandwidth mission or administrative voice, video and data streaming to any spaceport location in support to mission requirements.
- Provide 10GB/sec capability to all end users.

10.3 Institutional < 2015



10.3 Institutional >2015



Spaceport and Range Observations

Customer Satisfaction

- All Spaceports/Ranges have both common and unique needs as a result of their individual missions and customer base
  - Investments should be balanced on common needs as well as those carrying the highest national priority
- Improvement in turnaround times from test, development and launch activities should be area for continual improvement
  - Infrastructure : balance between sustaining current capability and new capability
  - Balance between resources constraints (people/funding) vs technology solutions
- Space-based communications capability should assume need for larger data volumes (e.g., power, antennas, etc.)
- Improved range and spaceport planning and scheduling capabilities should be implemented as part of continual improvement efforts
- Consistent with National Space Transportation Policy, all operators/users should seek to maximize use of commercial goods and services
  - eg satellite processing and general storage and support activities
- Reduced Spaceport and Range operations costs will continue to be a noble goal

Spaceport and Range Observations

Public Safety

- Models should be improved and true independent IV&V should be pursued
  - Weather prediction and safety calculations for blast and toxic
- Consider a center of excellence for models
- If a need is identified, development of models for nuclear generators and engines should be pursued
- Unique facilities to support nuclear activities may be needed as well

Observations on Non-technology Issues

The following items were identified during the Committee's deliberations and could be potential for forward-work for proposed Spaceport/Range Steering Committee:

- Launch Property at major federal ranges is becoming very scarce
  - Many demands for use and "ownership" exist
  - Likely not good planning to allow it to be reallocated to a single user before all space exploration requirements are known
- The FAA and the AF continue to work towards a joint safety regulation that could impact the commercial and government market place for rockets
  - Must preclude dual safety certifications
  - Must insure that additional costs not occur as a result of the dual/joint regulation environment
  - Need to include NASA in the dialogue
- Range encroachment, physical and RF, decrease the flexibility of operations
- Balance International participation with Homeland Security at Federal Ranges
  - Foreign entities access to Federal property
- Improvements needed to administrative accommodations at Spaceport for all users

A Transformational Thought

- The national ranges are crowded and becoming more so
- Design Test & Evaluation (DT &E) type range testing for range purposes is very difficult to fit in, can be risky, and precludes launch opportunities (RSA and other upgrades)
- Interplanetary windows could easily be impacted
- Basic capability exits to do these tests but it may not be the optimal method
- A range like Wallops Flight Facility may be best adapted to do range test and evaluation of new software or hardware for ranges
  - Test and transport of operational ranges for rapid insertion

Why a Wallops-Like Test Range Concept?

Wallops characteristics

- Lower overhead
- More schedule availability
- Aligns with existing Wallops culture & NASA-assigned mission
  - Focus on development activities & test missions
  - Can leverage existing NASA flight programs (e.g., Sounding Rockets) to provide low-cost technology demonstrations
  - Experience working with smaller users
  - Ability to demonstrate innovative approaches without compromising safety
- Experience in key transformational areas
  - Mobile range systems
  - Space-based and/or autonomous systems

What Might be Done on a Test Range for Ranges?

- Development of component systems like autonomous destruct or CRDs
- DT&E of common use range safety software and hardware
- DT&E of new common use hardware
- Test of new and truly mobile assets prior to operational range use and deployment
- Construction of other common user equipment
- Concept could include demonstration of key experimental flight system technologies that are best suited for a Test Range vs. Operational Range environment (e.g., prototype propulsion experiments, CEV crew-escape system demo, etc.)

Roadmap Conclusions

- Near-term Outlook:
  - Near term known mission requirements can be supported with current range and spaceports
  - There are areas that can be improved and/or life cycle costs that can be reduced once requirements identified and prioritized for investment

- Long-term Outlook
  - Transformational Spaceport and Range Roadmap has been focused on a requirements-driven approach with emphasis directed toward Program-unique and/or common user needs
  - Recommend the roadmap have careful review on a regular basis as the public safety and user requirements are identified and prioritized

Next Steps

- This Roadmap product is/should be a living document – this interim report is the initial step
- Committee will continue to refine requirements and develop investment strategies, using the best available customer milestones and data
- Report will be developed/submitted by June 2005
- NASA should continue to maintain a Spaceport/Range Steering Committee
  - Chaired by NASA HQ and co-chaired externally
  - Select membership by Centers and other stakeholders
  - Continued review of strategies for NASA investments into S&R capabilities and associated technologies as the Space Exploration initiative evolves

NRC Questions to be Answered

- Do the Capability Roadmaps provide a clear pathway to (or process for) technology and capability development?
- Are technology maturity levels accurately conveyed and used? (Note: Maturity levels will be evaluated using Technology Readiness Levels (TRLs) and Capability Readiness Levels (CRLs) or other appropriate methodologies)
- Are proper metric for measuring advancement of technical maturity included?
- Do the Capability Roadmaps have connection points to each other when appropriate

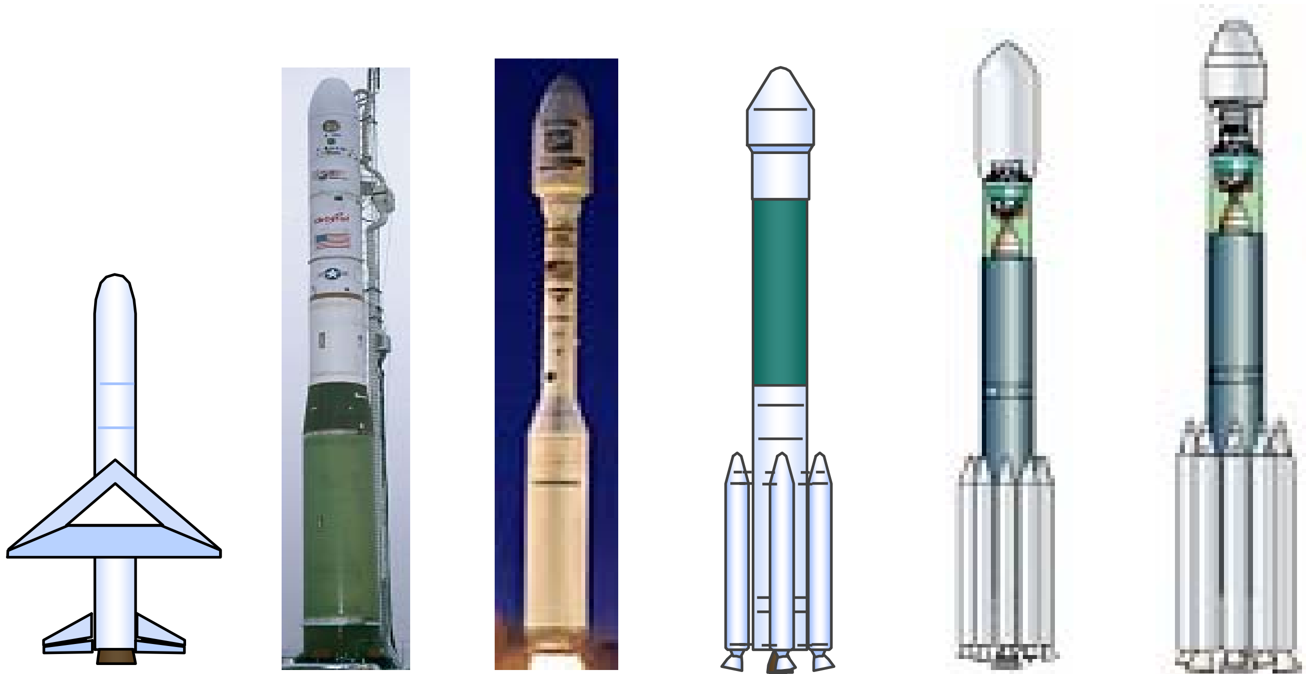
Acronyms and Abbreviations

AFRL	Air Force Research Laboratory
AFSPC	Air Force Space Command
AFSCN	Air Force Satellite Control Network
APIO	Advanced Planning and Integration Office (NASA)
ARD	Autonomous Rendezvous Docking
ARTWG	Advanced Range Technologies Working Group
ASTWG	Advanced Spaceport Technologies Working Group
CaLV	Cargo Launch Vehicle
CCAFS	Cape Canaveral Air Force Station
CDR	Critical Design Review
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
CoFR	Certification for Flight Readiness
CRD	
CRL	Capability Readiness Level
DARPA	Defense Advanced Research Projects Agency
DDT&E	Design, Development, Test and Evaluation
DoD	Department of Defense
ECLSS	Environmental Control/Life Support System
EDS	Earth Departure Stage
EELV	Evolved Expendable Launch Vehicle
FAA	Federal Aviation Administration
FAST	Flight Application of Spacecraft Technology
FIRST	Future Interagency Range & Spaceport Technologies
GB/Sec	Giga-Byte/Second
GPS	Global Positioning System
GSS	Ground Support Systems
HQ	Headquarters
IOC	Initial Operations Capability
ISS	International Space Station
IV&V	Independent Verification and Validation
KSC	Kennedy Space Center
LCC	Launch Control Center
LCN	Lunar Communications and Navigation
LSAM	Lunar Surface Access Module
LV	Launch Vehicle
MDA	Missile Defense Agency
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NRO	National Reconnaissance Office
ORR	Operation Readiness Review
OSD	Office of Secretary of Defense
OSHA	Occupational Safety and Health Administration
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
QoS	Quality of Service
R&D	Research and Development
RF	Radio Frequency
RSA	Range Standardization and Automation
RTG	Radio-Isotope Thermal Generator
S&R	Spaceport and Range
SCAPE	Self-Contained Atmosphere Protective Ensemble
SCIF	Satellite Check-out and Integration Facility
SRB	Solid Rocket Booster
SRR	System Requirements Review
STARS	Space-based Telemetry And Range Safety
STS	Space Transportation System (aka Space Shuttle)
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
T&E	Test and Evaluation
TRL	Technology Readiness Level
US	United States
USAF	United States Air Force
USG	United States Government
VAFB	Vandenberg Air Force Base
VPP	Voluntary Protection Program
WFF	Wallops Flight Facility
WSTF	White Sands Test Facility

SUPPLEMENTAL DATA

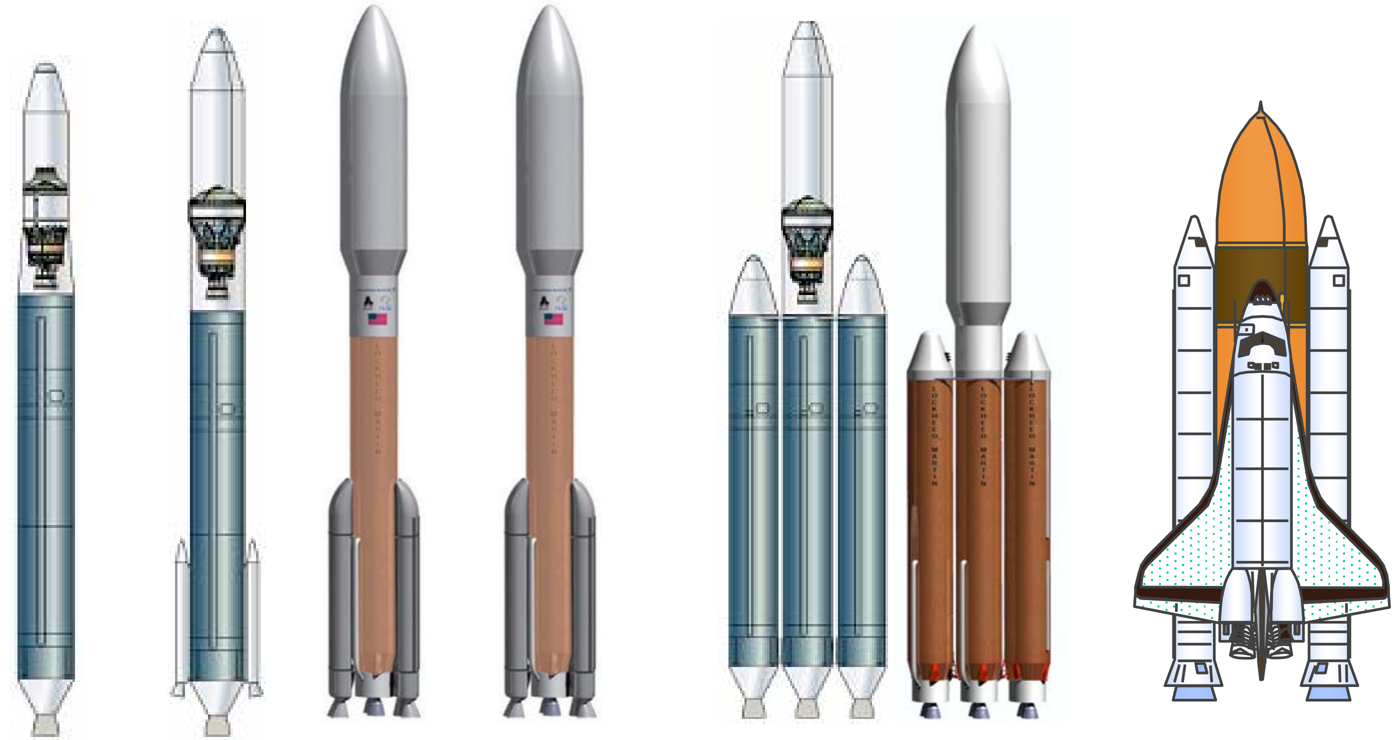
Not to be briefed, but in the package

Current Small US Launch Capability



Launch Vehicle	Pegasus	Minotaur	Taurus	Delta II 73XX	Delta II 79XX	Delta II 79XXH
Supplier	Orbital Sciences Corp.	Orbital Sciences Corp.	Orbital Sciences Corp.	Boeing	Boeing	Boeing
LEO (kg)	453	291	568	2,796	5,140	6,000
SSO (kg)	191	145	302	1,685	3,220	No WTR
ISS (kg)	350	N/A	455	2,435	4,440	5,200
GTO (kg)	N/A	N/A	N/A	1,000	1,870	2,100
High Energy C3=0	N/A	N/A	N/A	725	1,250	1,500
High Energy C3=10	N/A	N/A	N/A	600	1,000	1,300

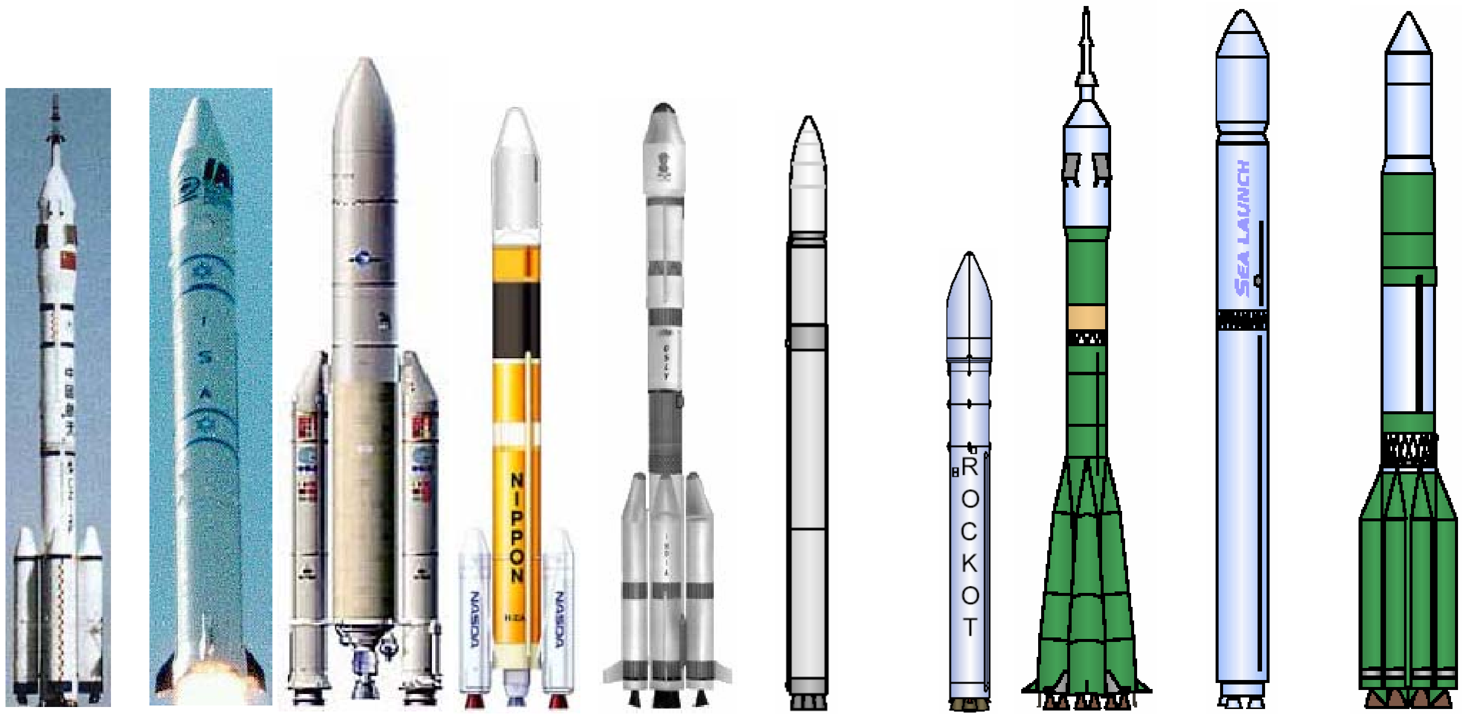
Current Large Class US Launch Capability



Launch Vehicle	Delta IV 4040	Delta IV 4450	Atlas V 50X	Atlas V 55X	Delta IV Heavy	Atlas V Heavy	Space Shuttle
Launch Service	Boeing	Boeing	LM	LM	Boeing	LM	NASA
LEO (kg)	8,600	13,100	9,540	18,000	23,165	U/R	22,600
SSO (kg)	6,300	9,600	No WTR	No WTR	21,040	No WTR	N/A
ISS (kg)	7,700	11,800	8,500	17,500	23,900	25,500	16,800
GTO (kg)	3,985	6,345	3,880	8,570	12,650	12,200	2200*
High Energy C3=0	2735	4,580	2680	6330	9305	9000	N/A
High Energy C3=10	2115	3,685	2150	5300	7810	7500	N/A

* Assumes IUS Upper Stage

Foreign Launch Capability



Pictures not to scale

Launch Vehicle	LM 2F	Shavit	AR 5	HII A	GSLV	Dnepr	Rockot	Soyuz	Zenit Sealaunch	Proton
Country	China	Israel	France	Japan	India	Russian	Russian	Russian	Russian	Russian
LEO (kg)	8,000	300	21,000	10,000	5,000	4,500	1,900	7,300	N/A	21,000
SSO (kg)	N/A	N/A	N/A	4,360	N/A	N/A	N/A	4,400	N/A	N/A
ISS (kg)	N/A	N/A	21,000	9,000	N/A	N/A	N/A	7,300	N/A	21,000
GTO (kg)	N/A	N/A	10,050	4,000	2,500	N/A	N/A	1,500	6,000	4,585
High Energy C3=0	N/A	N/A	6,000+	N/A	N/A	N/A	N/A	1,600	4,000	N/A
High Energy C3=10	N/A	N/A	5,500	N/A	N/A	N/A	N/A	1,200	3,000	N/A

Performance figures reflect publicly available advertised data
N/A = No known/advertised existing capability for respective trajectory

Crosswalk Matrix Ratings
Work In-progress

- Critical Relationships (Red):
  - Communications and Navigation Roadmap
    - Space-based assets for telemetry/tracking
- Moderate Relationships (Blue):
  - High Energy Power & Propulsion Roadmap
    - Potential unique launch site facilities/infrastructure needs for processing nuclear power sources/propulsion
  - In-space Transportation Roadmap:
    - Vehicle processing – pre-launch and launch
    - Telemetry/Tracking
  - Human Planetary Landing Systems Roadmap
    - Vehicle processing – pre-launch and launch
    - Telemetry/Tracking
  - Human Health and Support Systems Roadmap
    - Spaceport Infrastructure for crew pre-launch processing
    - Crew support equipment at launch site
    - Pad infrastructure (e.g., life support, comm, video, safety, etc.) for crewed vehicle
  - Advanced Modeling, Simulation, Analysis Roadmap
    - Modeling/Analysis for Range Safety (e.g., flight control ops, debris field analysis, expected casualty analysis, etc)
  - Systems Engineering Cost/Risk Analysis
    - Requirements Development, Design, Development of new Spaceport/Range Technologies

Wallops Mobile Range Mission Locations (Since 1983)

Full Mobile Range Missions/Campaigns

- Peru (1983) – ***Sounding Rocket Campaign***
- Fort Yukon, AK (1984)- ***Sounding Rocket Campaign***
- Fort Churchill, Canada (1983, 1984, 1989) – ***Sounding Rocket Campaigns***
- Sonde Stromfjord, Greenland (1985, 1988) – ***Sounding Rocket Campaigns***
- Woomera, Australia (1989, 1997) – ***Sounding Rocket Campaigns***
- Puerto Rico (1992, 1998) – ***Sounding Rocket Campaigns***
- Alcantara, Brazil (1994) – ***Sounding Rocket Campaign***
- Svalbard, Norway (1998, 2003) **- *Sounding Rocket Campaigns***
- Canary Islands (1997) – ***Pegasus ELV Mission***
- Kodiak, AK (2001) – ***Athena ELV Mission***

Partial Mobile Range Missions/Campaigns

- Poker Flat Research Range (Every 1-2 years) – ***Sounding Rocket Campaigns***
- Andoya, Norway (Every 2-3 years) – ***Sounding Rocket Campaigns***
- Kiruna, Sweden (Every 2-3 years) - ***Sounding Rocket Campaigns***
- Kwajalein Atoll (1990, 2004) – ***Sounding Rocket Campaigns***
- Midwest, USA (1998-1999) – ***X-33 Downrange Support***
- Coquina, NC (Every 1-2 years) – ***Wallops Downrange Support***

KSC Capabilities and Infrastructure

- 140,000 acres (218 square miles)
  - 70,000 acres of estuary deemed a system of National Importance
  - Located within confines of the Merritt Island National Wildlife Refuge and the Canaveral National Seashore
    - 6,800 acres for NASA activities
  - 27 State and Federally protected species, 11 of which are listed as threatened or endangered
- Over 7.2 million sq. feet of Building area
  - 3 fire stations
  - 2 medical facilities
- Utilities
  - 3 Central Cooling/Heating Plants
  - 2 Primary Substations
  - 270 miles of Electrical Distribution Lines
  - 60 miles of high pressure Helium/Nitrogen Pipelines
  - 46 miles of wastewater pipelines
  - 90 miles of water distribution pipelines
- Transportation
  - Shuttle Landing Facility (15,000 foot runway)
  - 540 miles of Roadway (paved and unpaved)
  - 2 Sea Docks
  - 40 miles of Railroad
  - 5 Major Bridges
- KSC Core Technical Capability (CTC) is comprised of the Center's multi-customer laboratories, critical competency sustenance and essntial technical services
  - CTC supports multiple enterprises and themes.

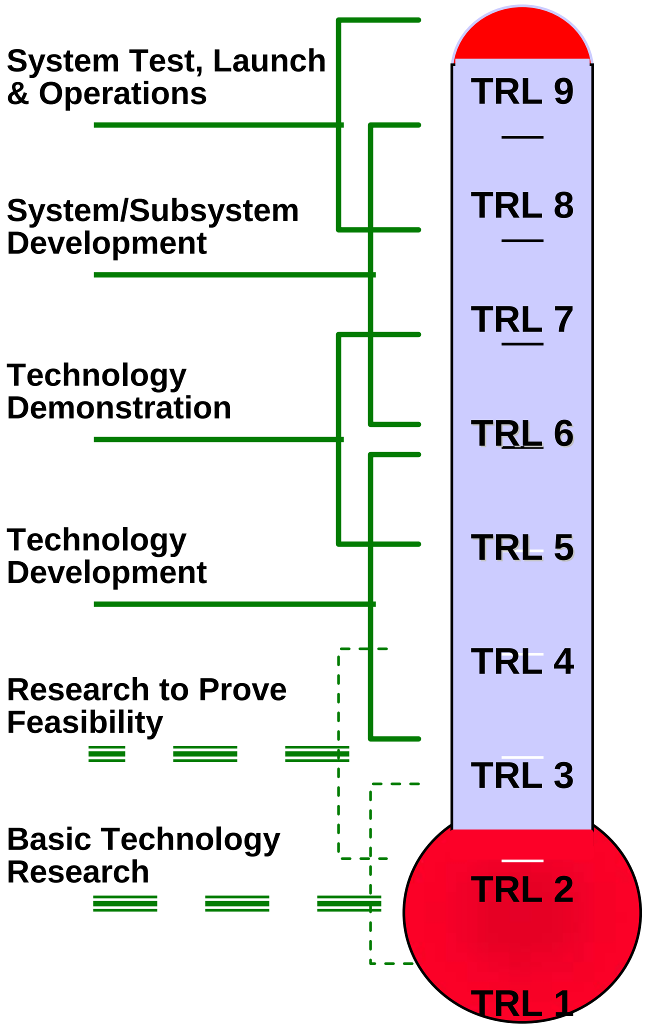
Approx. $4B Current Replacement Value

CTC Labs/Test Beds

John F. Kennedy Space Center

- KSC Core Technical Capability (CTC) is comprised of the Center's multi-customer laboratories, critical competency sustenance and essential technical services.
  - CTC supports multiple Enterprises and themes
- Civil Service Labs/Testbeds
  - Metrology
  - Physical Test & Analysis
  - Chemical Test & Analysis
  - Development & Integration
  - Electrical Failure Analysis
  - Materials Failure Analysis
  - Bio-Medical
  - Telescience
  - Design Visualization
  - Real Time Control & Monitoring
  - Controls
  - Applied Physics
  - Electrostatics & Surface Physics Testbed
  - Launch Systems Testbed
  - Advanced Technology Development Center
  - Spaceport Processing Systems

TECHNOLOGY READINESS LEVELS



Actual system proven through successful mission operations

Actual system completed and qualified through test and demonstration

System prototype demonstration in a relevant environment

System/subsystem model or prototype demonstration in a relevant environment

Component and/or breadboard validation in relevant environment

Component and/or breadboard validation in laboratory environment

Analytical and experimental critical function and/or characteristic proof-of-concept

Technology concept and/or application formulated

Basic principles observed and reported

Capability Readiness Levels

7 Capability Operational Readiness

6 Integrated Capability Demonstrated in an Operational Environment

5 Integrated Capability Demonstrated in a Relevant Environment

4 Integrated Capability Demonstrated in a Laboratory Environment

3 Sub-Capabilities* Demonstrated in a Relevant Environment

2 Sub-Capabilities* Demonstrated in a Laboratory Environment

1 Concept of Use Defined, Capability, Constituent Sub-capabilities* and Requirements Specified

* Sub-capabilities include Technologies, Infrastructure, and Knowledge (process, procedures, training, facilities)