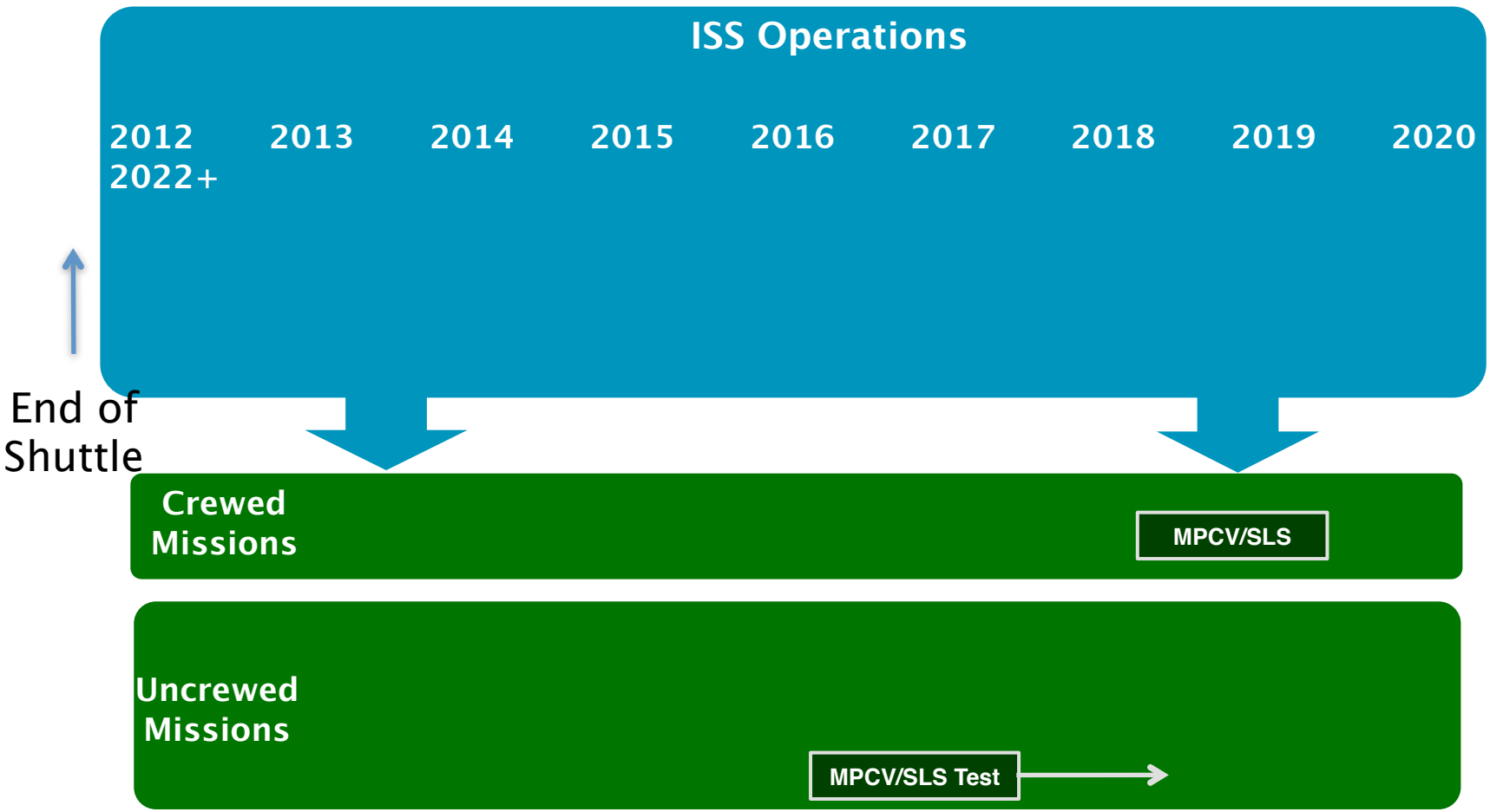
Toward Deep Space Exploration: Small Steps versus One Giant Leap

Andrew Thomas

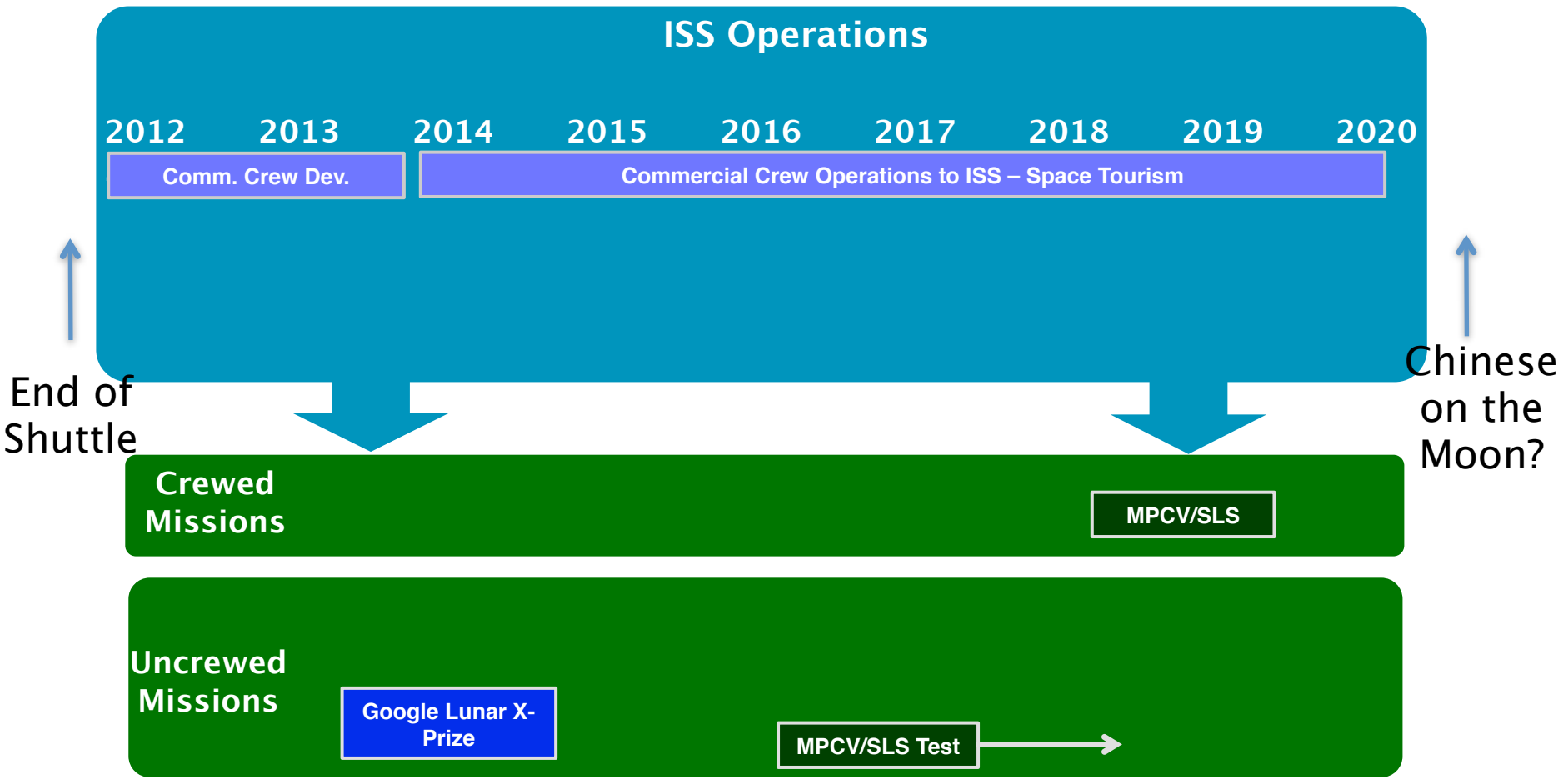
Sept 6, 2011

The Emerging Environment and The Gap



The Emerging Environment and The Gap

When Commercial Crew succeeds, the public will start to ask – Why do we need NASA? – The Agency needs some tangible advances (Fire and Smoke!)



The next decade in human space flight will be challenging for the Agency

Some National Human Space Flight Projects

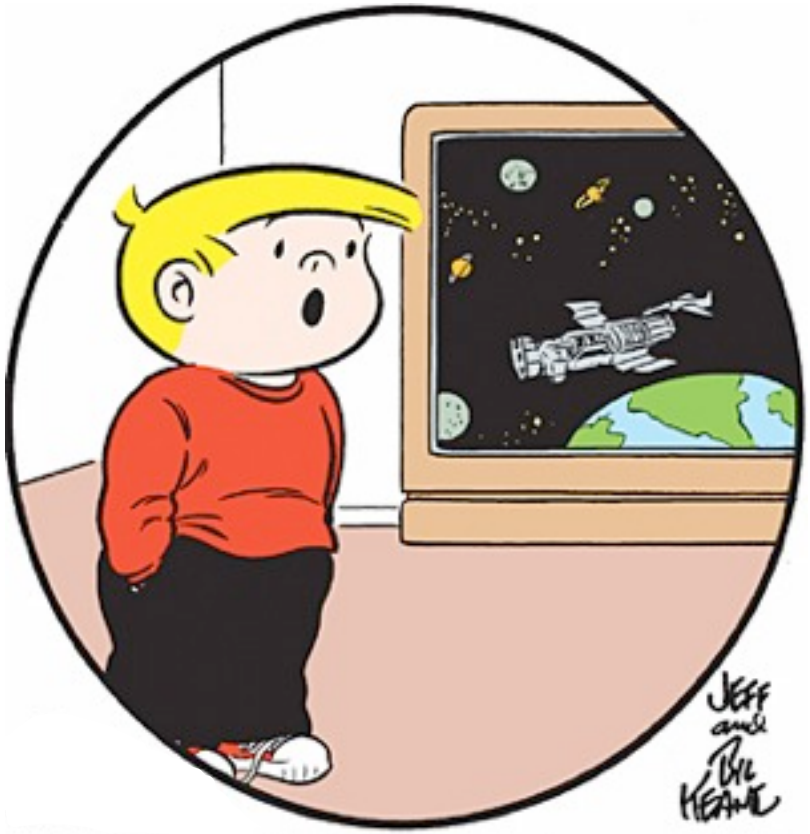
- **Apollo** – Cancelled as soon as goal was achieved – we should not forget that public interest wanes very quickly
- **Shuttle** – Approved for defense reasons, but started becoming unsustainable after DOD pulled out, and cancelled after Columbia
- **SEI** – Congressional 'sticker shock' and cancelled
- **ISS** – Suffered the legacy of 'Freedom', passed by only 1 vote, saved by Russian partnership
- **VSE and Constellation** – Politically and economically unsustainable

More programs are cancelled than finished – This

Why Have Big National Programs Become

- **Irrelevance** – When they are seen as no longer relevant (e.g. Apollo after July 1969)
- **Affordability Sticker Shock** – When they are seen as not cost effective – e.g. Ares I was cancelled but Space X support continues

  (Not to be confused with cost over runs – James Webb will probably fly)
- **Lack of Progress** – When there is little perceived progress forward in a way that has value in the eyes of the public (e.g. Freedom)



"Someday I might travel to another planet, but I'm not sure why."

"Boldly Going" Is Not Enough: Need to be Relevant History Tells Us What That Means

- **Economic Security/Commerce:**
  - Columbus and 1492
  - Interstate Highway System
  - Tennessee Valley Authority, TVA

Wealth

- **National Security/Defense:**
  - Great Wall of China
  - Manhattan Project
  - Interstate Highway System
  - Apollo, Shuttle, Freedom

War

- **Spiritual Security/Deity:**
  - The Pyramids
  - Gothic Cathedrals
  - The Crusades
  - Apollo

Wonder

Today, successful programs must be seen to have relevance in one or more of these areas, and it must be near term

Affordability – NASA Annual Budget Then-Year Dollars, 1990 – 2011

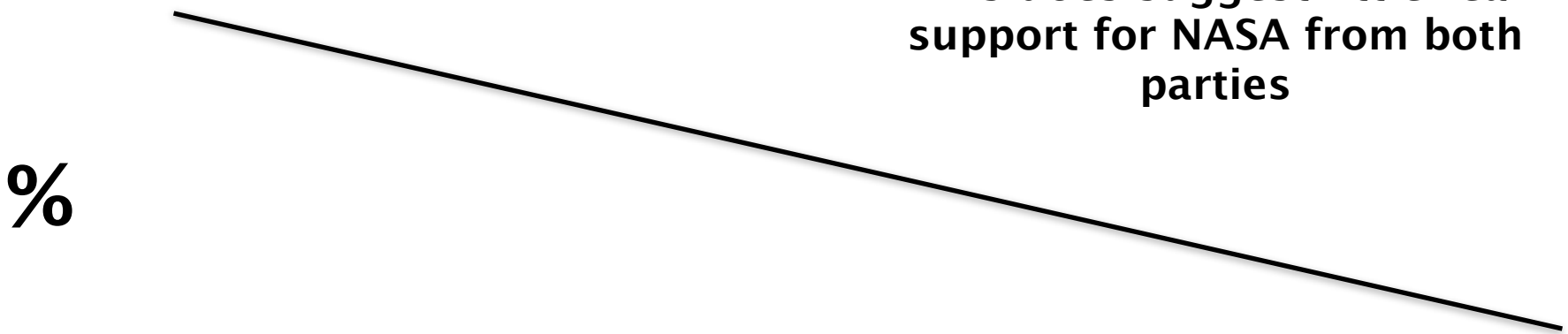
$M

Affordability – NASA Annual Budget as Percentage of Federal Budget, 1990 – 2011

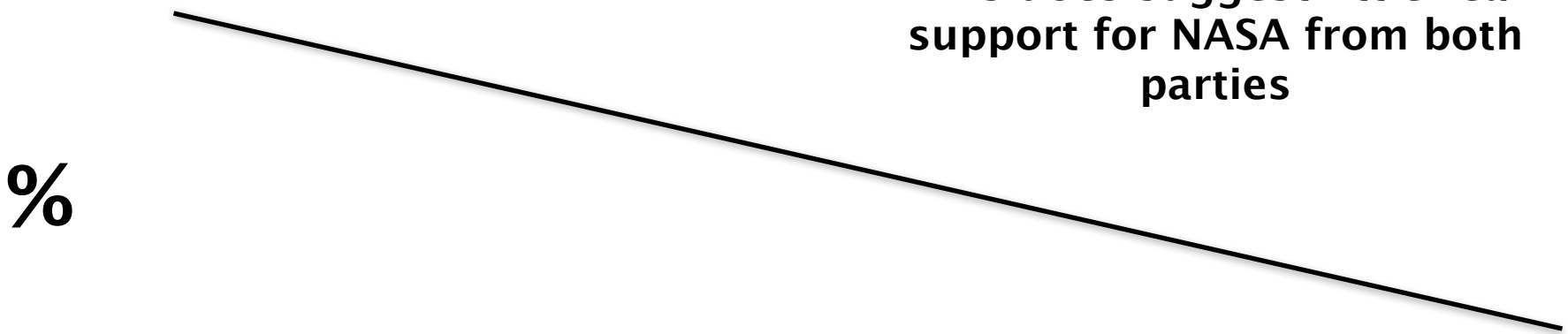
This does suggest little real support for NASA from both parties

%

Affordability – NASA Annual Budget as Percentage of Federal Budget, 1990 – 2011



Affordability – NASA Annual Budget as Percentage of Federal Budget, 1990 – 2011



NASA Budget will be zero in 2030!
(or Federal Budget will be infinite!)

Affordability – NASA Annual Budget in 1991 Dollar 1991 – 2011

$M

This will likely trend further downward in coming years – Big $ programs will come under scrutiny

Progress – What Does That Actually Mean?

- **The visible progress of the lunar program contributed to its success (Mercury, Gemini, Apollo 8)**
- **The perceived lack of progress of 'Freedom' contributed to its demise**
- **The shuttle program was seen as not advancing and that was another contributing factor to its cancellation (CAIB asked why were we doing this?)**
- **Progress must be demonstrable and visible, that is it must have 'street appeal' rather than arcane science and engineering**
  - Kepler has found > 1000 exo-planets, but does the public care?

Progress must exist in the eyes of Congress

The Challenge – National Relevance, Affordability and Progress

- **Relevance** – Without support from one or more of the Big 3 'Wealth, War or Wonder', large scale, expensive national programs are not viable
- **Affordability** – There seems to be a 'cost threshold' of about $1B above which activities become too visible and therefore vulnerable
- **Progress** – Whatever we do must have demonstrable progress. For the public this requires 'street appeal', and not just arcane engineering advances

The Agency has many missions in study, but how many of them match to one or more of these challenges?

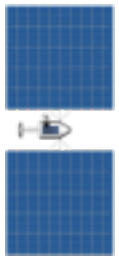
In the Face of Modern Realities
No More Giant Leaps, So Take Small Steps

- Can we assemble a series of small projects (not big programs) that are short-term, acceptable in risk and cost, and individually show tangible progress (street appeal), but…..
- ……but which in aggregation are such that they build toward a collective deep space capability and support national interests
- This requires frugal and innovative ways to produce 'Beyond-LEO' transportation elements while keeping costs below the $1B visibility threshold
  - Exploit partnerships (international, commercial) – but that is not enough
  - Utilize existing assets to the greatest practical extent (reuse, re-purpose, etc.)
  - Integrate with other current or planned flight projects to the greatest extent
  - Use ISS as an Exploration Development and Flight Test Center
  - Use Robotic missions, tactically, to flight qualify systems and sustain public interest

Use an integrated cadence of small missions to

Enablers for Deep Space Travel

Solar Electric Propulsion



- Specific impulse = 2000 s
- Total power = 300 kWe

Chemical Propulsion Stage

- LOX/LH2
- Zero-boiloff cryo management
- Specific impulse = 455 s

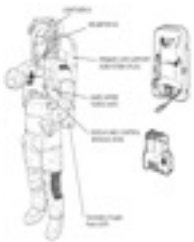
Deep Space Habitat

- Sized for a crew of 4 for 400 days
- Total Volume ~168 m^3
- Nominal mass ~ 28 t

Space Exploration Vehicle

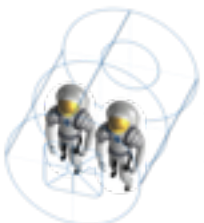
- Primary purpose is for exploration of NEA's
- Supports crew of 2 for 28 days
- Nominal mass = 6.6 t

Advanced EVA



- Exploration suit development
- Suit-port based

Robotics EVA Module



- Provides EVA support
- Provides robotic manipulators

Multi Purpose Crew

- Same assumptions as HEFT (CTVE-AE configuration)
- CM inert = 9.7 t
- SM inert = 4.7 t

Space Launch System

- Evolved SLS capability
- No specific design assumed
- Gross Performance ~ 130 t
- Net Performance ~ 120 t

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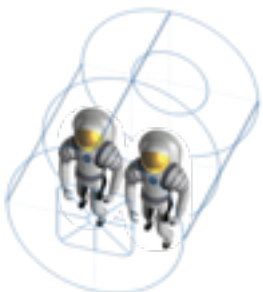
Possible Innovative Approaches – Crewed Elements

- **Deep Space Habitat (DSH) – It is all about the ECLSS:**
  - Send ECLSS systems up to ISS on an ATV and outfit current MPLM
  - Outfit Node STA or MPLM and launch to ISS on ELV (in planning)
  - Outfit commercially provided element with ECLSS etc. and launch

- **Space Exploration Vehicle (SEV):**
  - Utilize HTV as MMSEV systems test bed (Exploration Test Module, ETM, in planning)
  - Deploy MMSEV cab to ISS and operate on SSRMS (in planning)
  - Add RCS sled to MMSEV to create free flyer (in planning)



- **Robotics EVA Module (REM):**
  - Utilize shuttle airlock, RMS or 'Strella'
  - Utilize HTV, scavenge shuttle airlock systems

- **Advanced EVA:**
  - Utilize ISS as testbed and lever ISS resources

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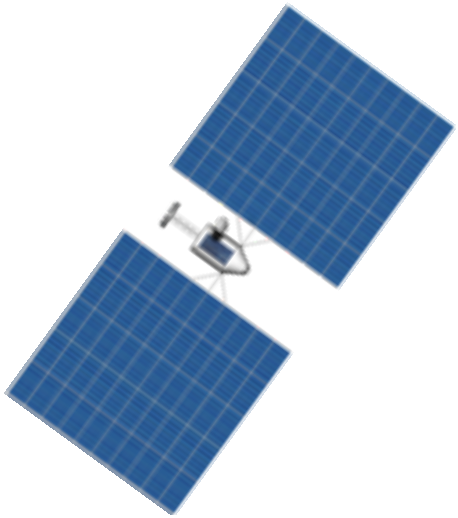
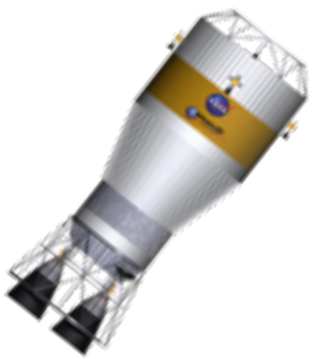
Possible Innovative Approaches – Propulsive Elements



- **Solar Electric Propulsion (SEP):**
  - Deploy candidate thruster on ISS for reboost (in planning)
  - Deploy candidate array on ISS to augment ISS power
  - But at some point a significant investment is needed



- **Cryo-Propulsion Stage (CPS):**
  - What upper stages are currently available that might provide interim support to deep space missions?
    - Russian – Briz-M, Block-D, Soyuz 3rd stage
    - US – Centaur, Falcon 9 2nd stage
    - Europe – EPS, ECA (Ariane 5 2nd stages)
    - Japan – H-IIB second stage

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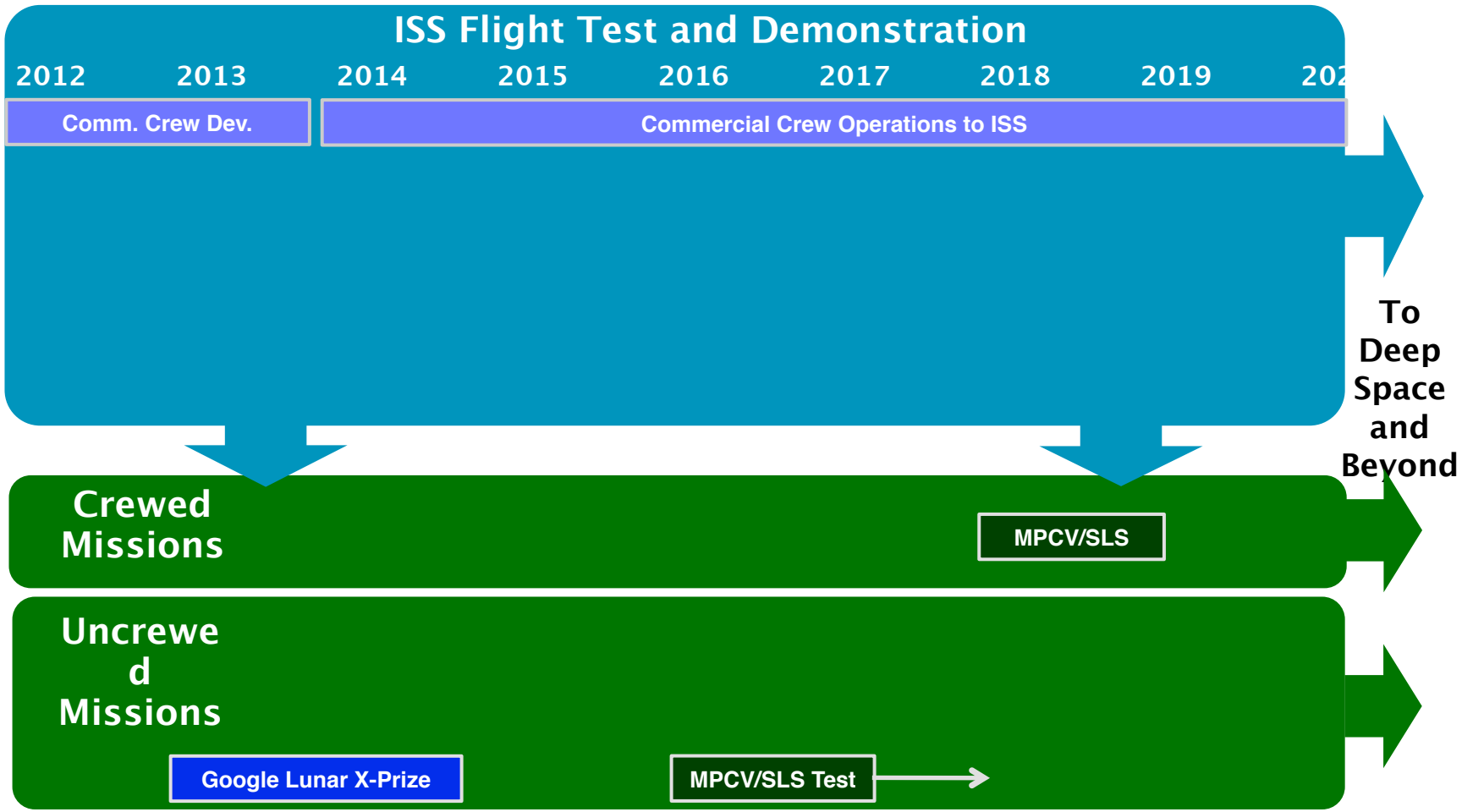
Build a Deep Space Capability on the Existing Agenc Activities



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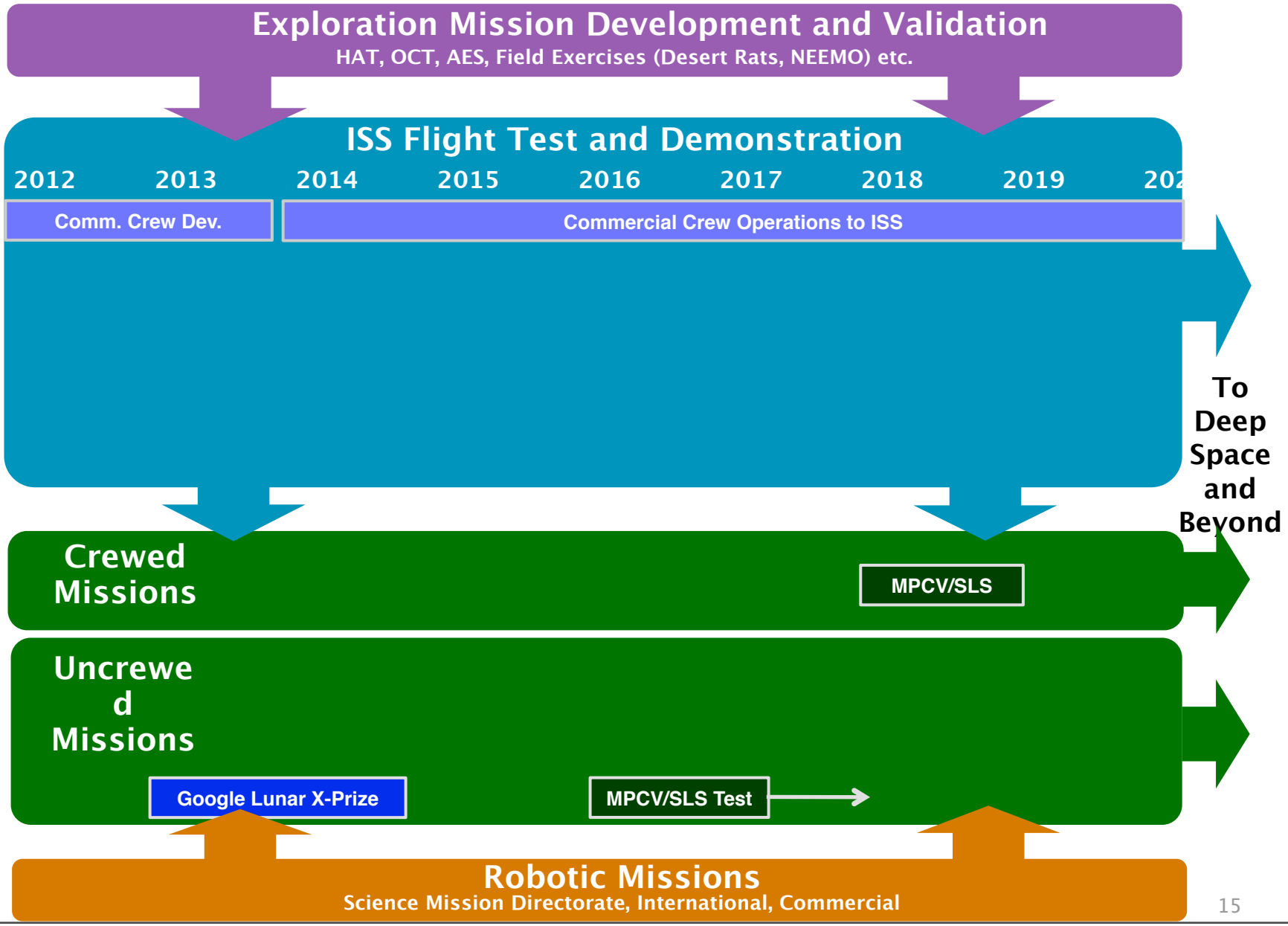

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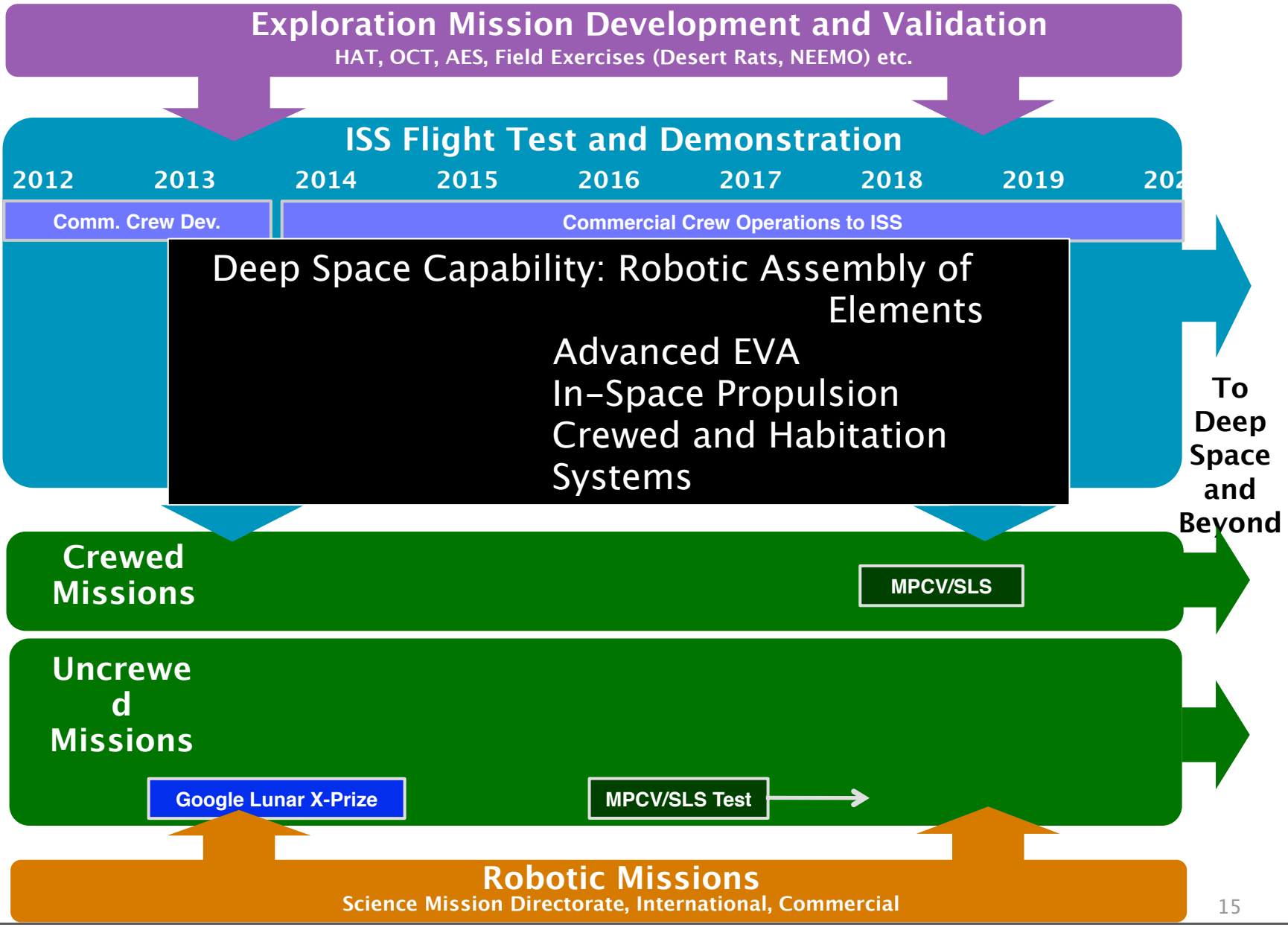
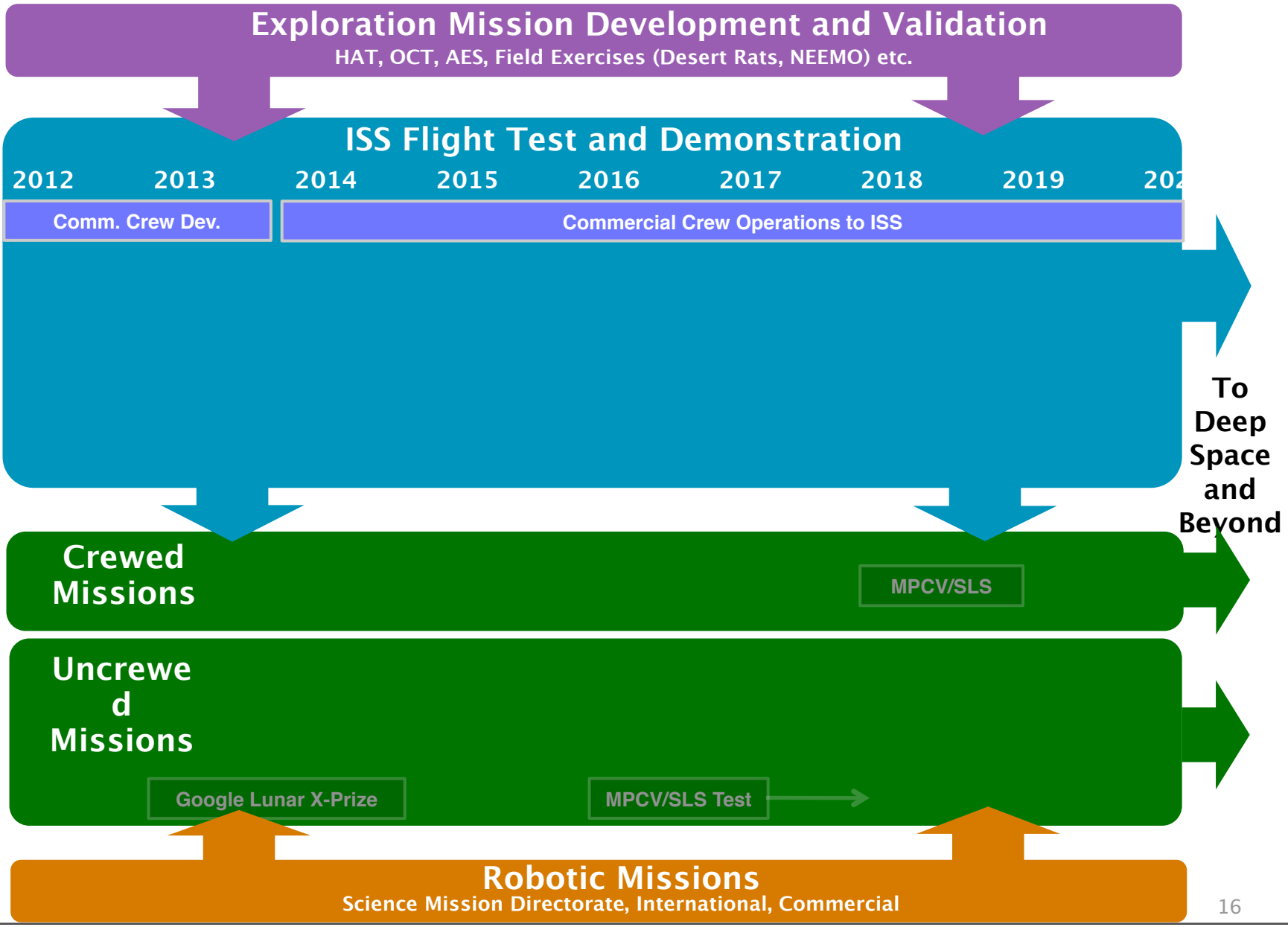
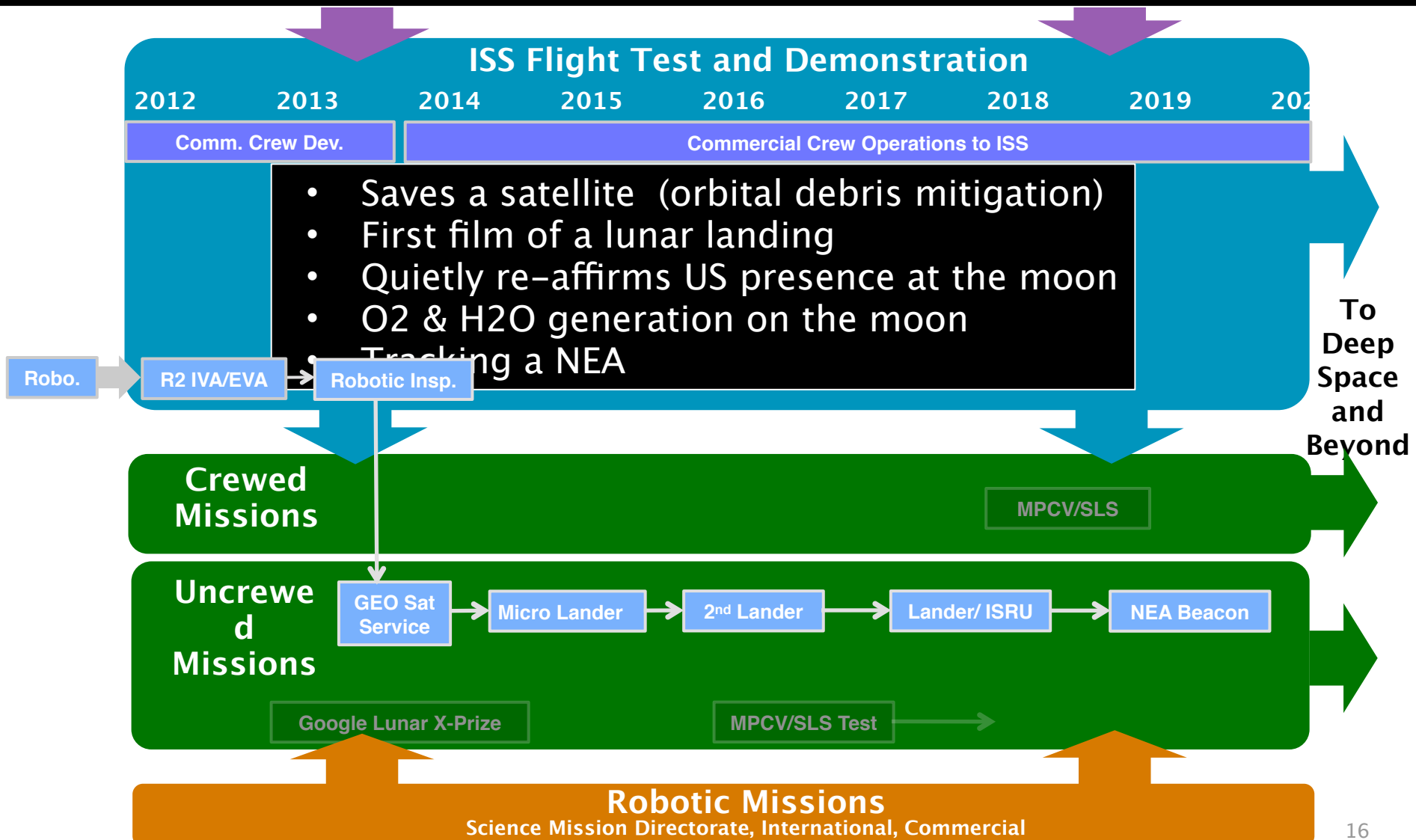


Make Tactical Use of Key Robotic Missions



Make Tactical Use of Key Robotic Missions

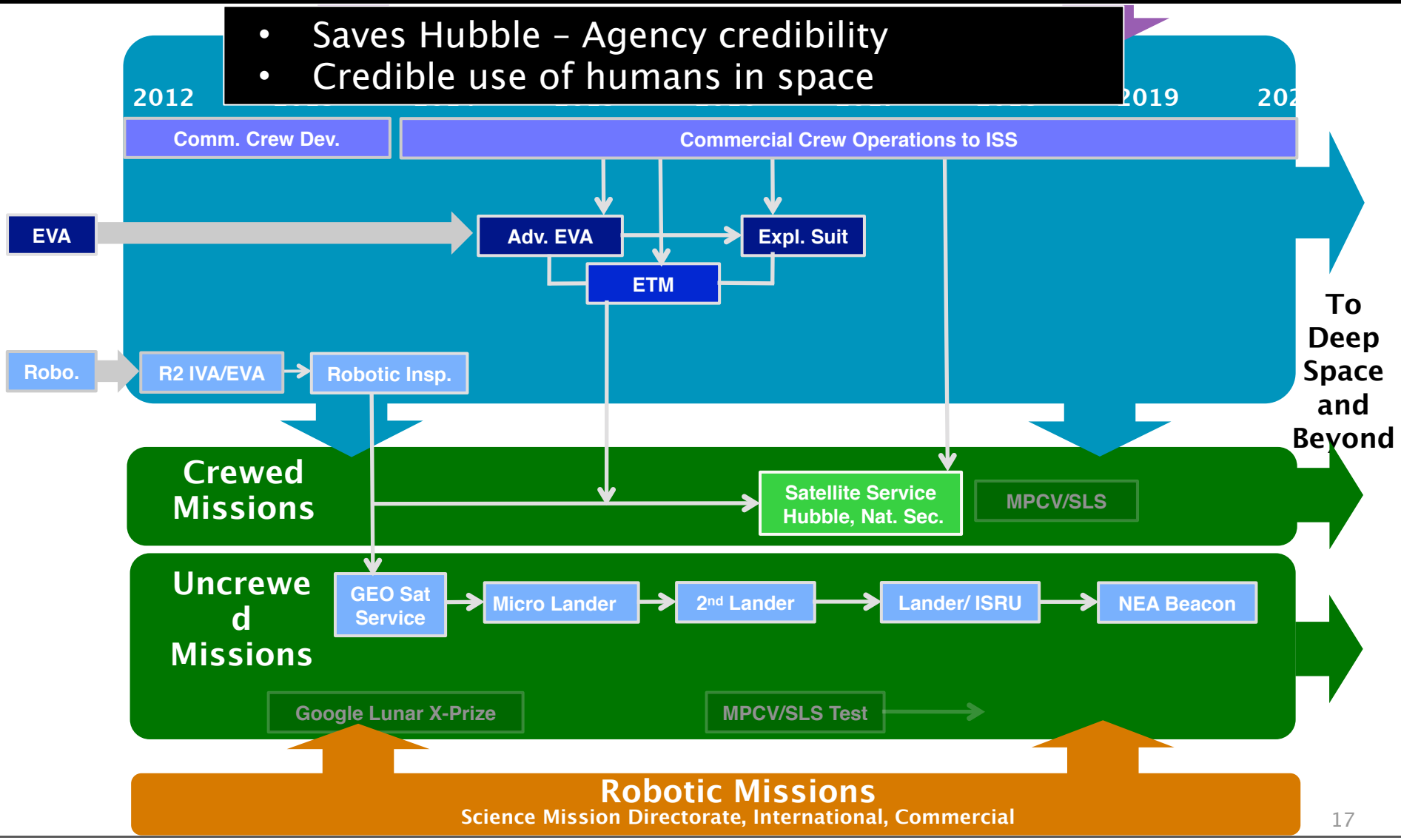
Start by filling the gap with robotic missions that build the capabilities needed for in-space assembly and deployment of deep space elements

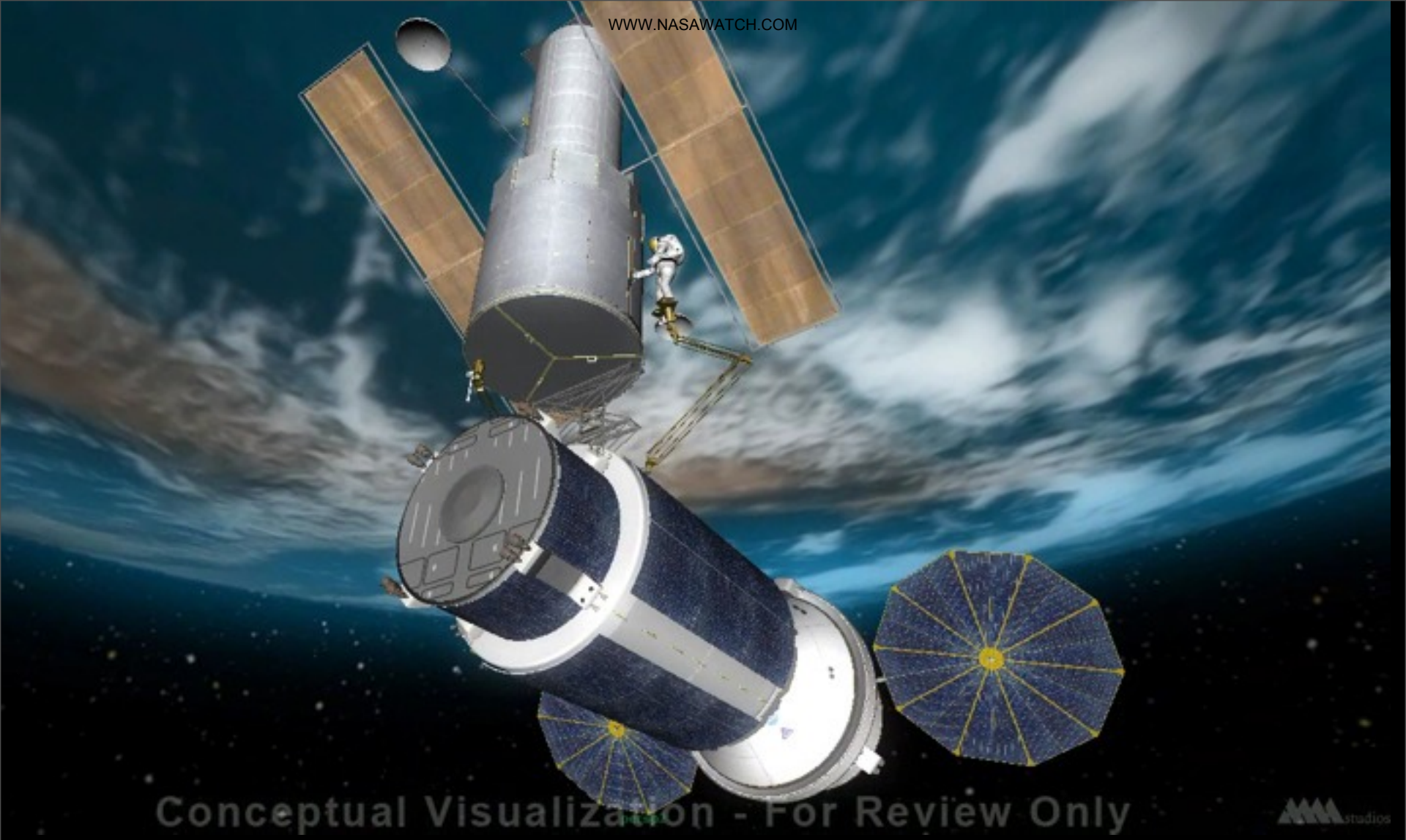


Demonstrate In-Space Servicing and Advanced EVA

Concurrently, develop advanced EVA and an Exploration Test Module (ETM) at ISS and follow with satellite or Hubble servicing mission

- Saves Hubble – Agency credibility
- Credible use of humans in space





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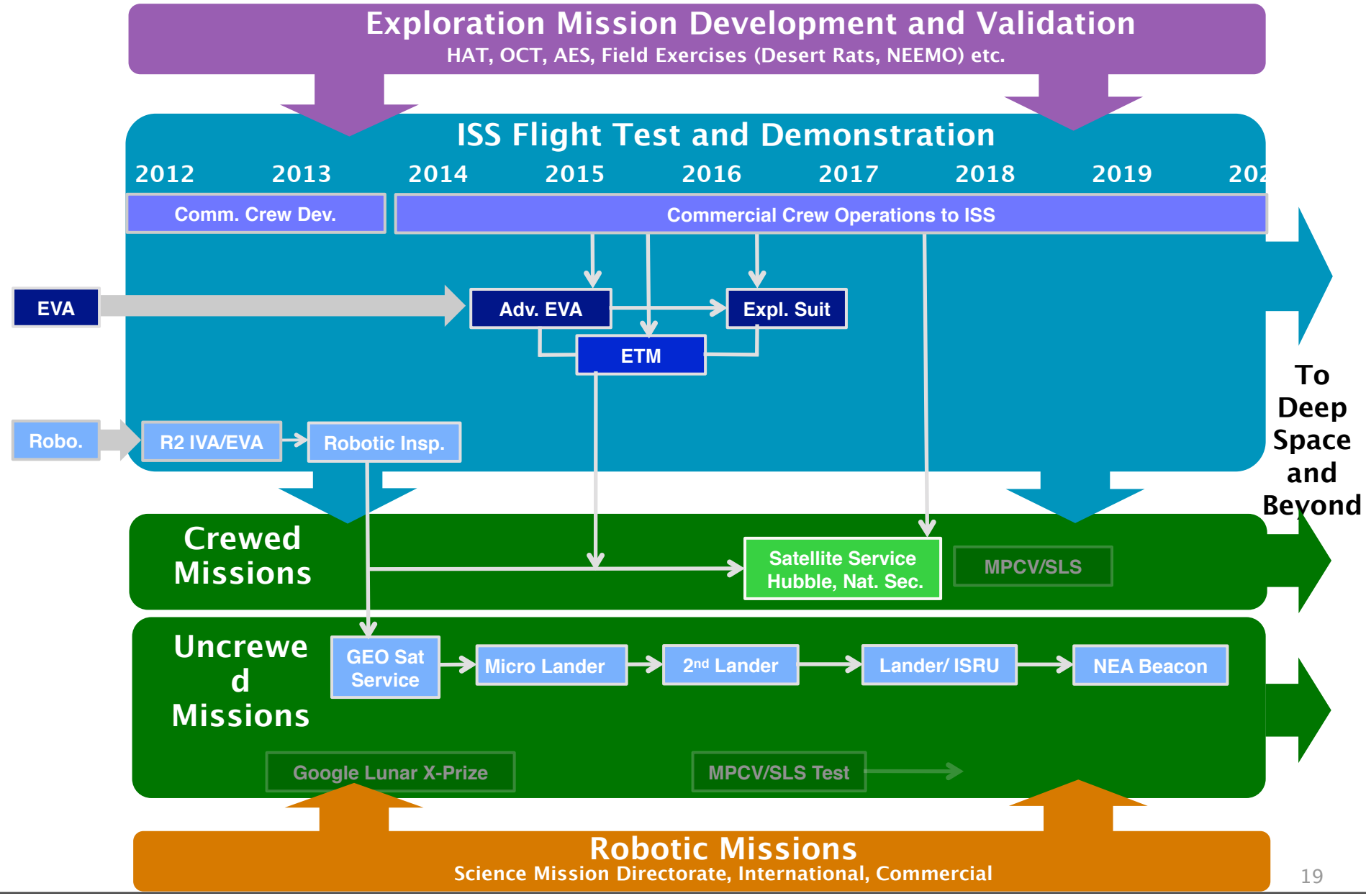
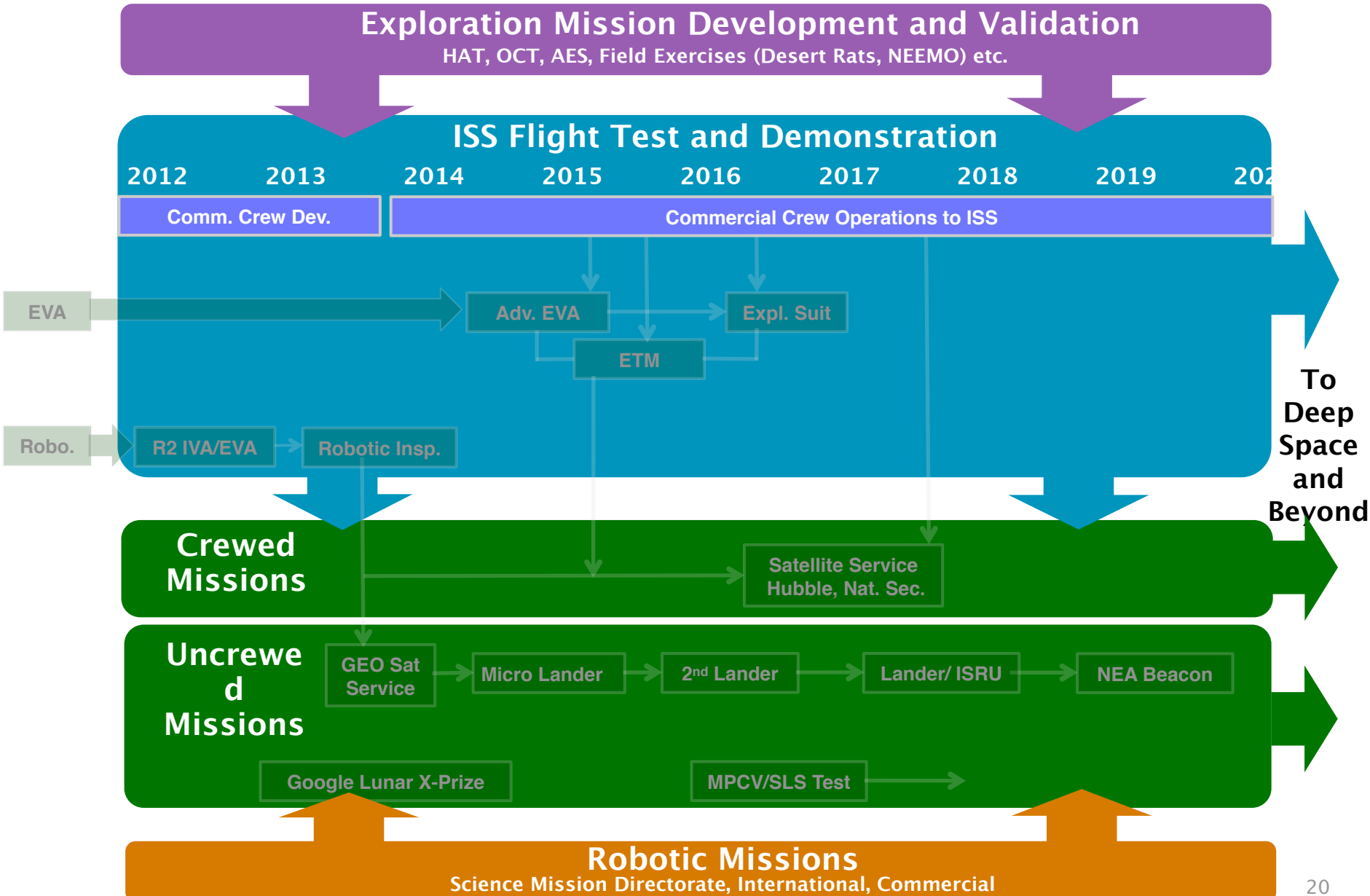
Establishes Uncrewed Assembly, Mission Ops., and Advanced EVA



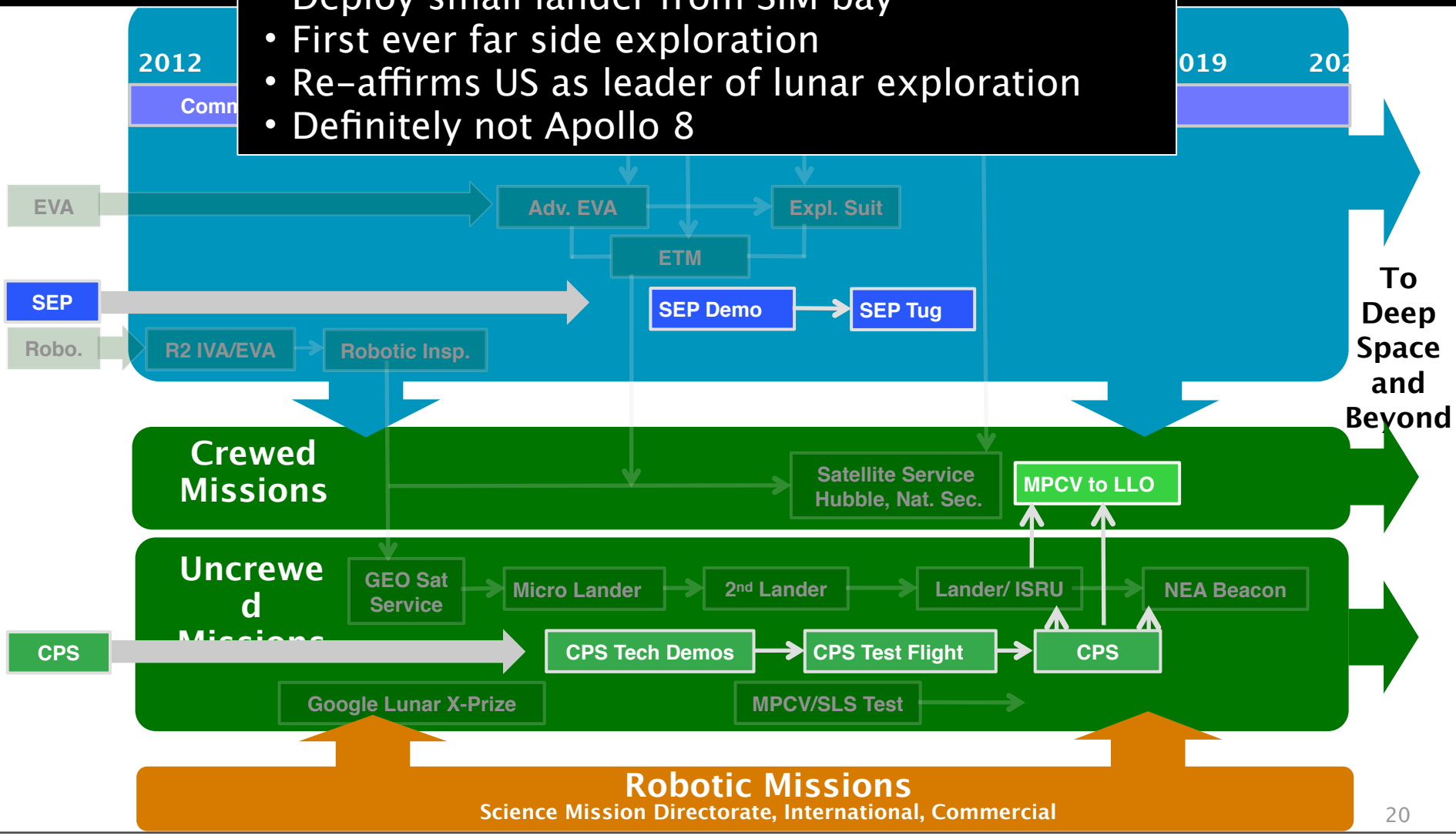
Develop Propulsion Systems for Deep Space



Develop Propulsion Systems for Deep Space

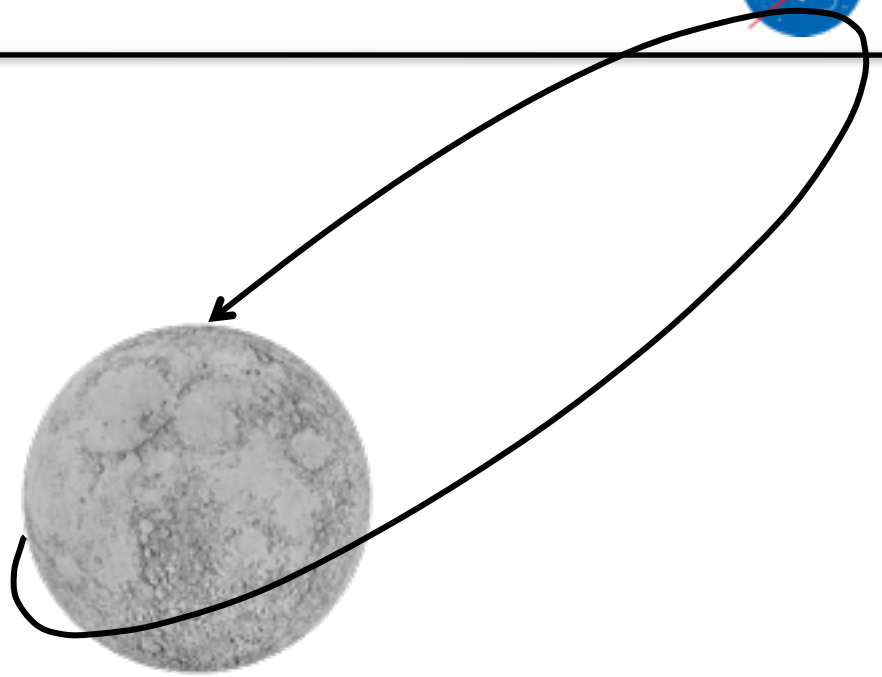
Using existing assets as much as possible, develop in-space propulsion capability, and then perform crew mission around moon as SLS/MPCV become

- Deploy small lander from SIM bay
- First ever far side exploration
- Re-affirms US as leader of lunar exploration
- Definitely not Apollo 8



Deployment of Robotic Lander from MPCV SIM Bay

- **Mission Concept:**
  - MPCV enters LLO (Apollo 8-like)
  - Small Lander is released from SIM bay
  - Lander lands autonomously at unique site e.g. Aitken basin
  - Small rover deploys from lander SIM bay
  - MPCV then enters highly-elliptical, high-apogee, low-perigee orbit
  - MPCV and crew over fly far side and provide control and comm to/ from rover

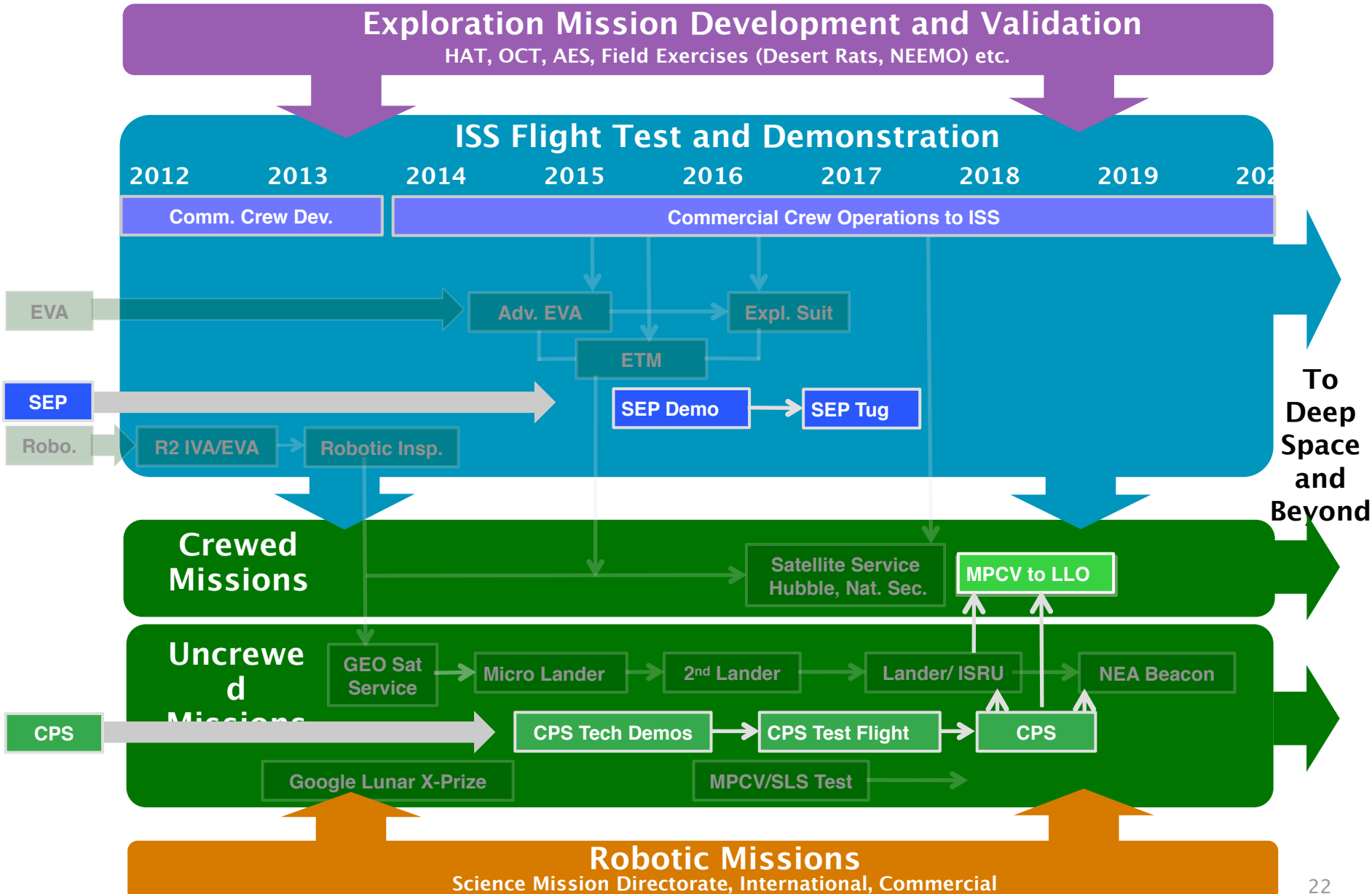


Without something like this, a lunar flyby in the MPCV will look just like a step back to 1968

Lander would be smaller than Surveyor, e.g.:

- 100 kg inert lander
- ~ 90kg of bipropellant to land
- Required SIM Bay is 0.8 x 0.8 x 0.8 m

In-Space Propulsion Capabilities Established



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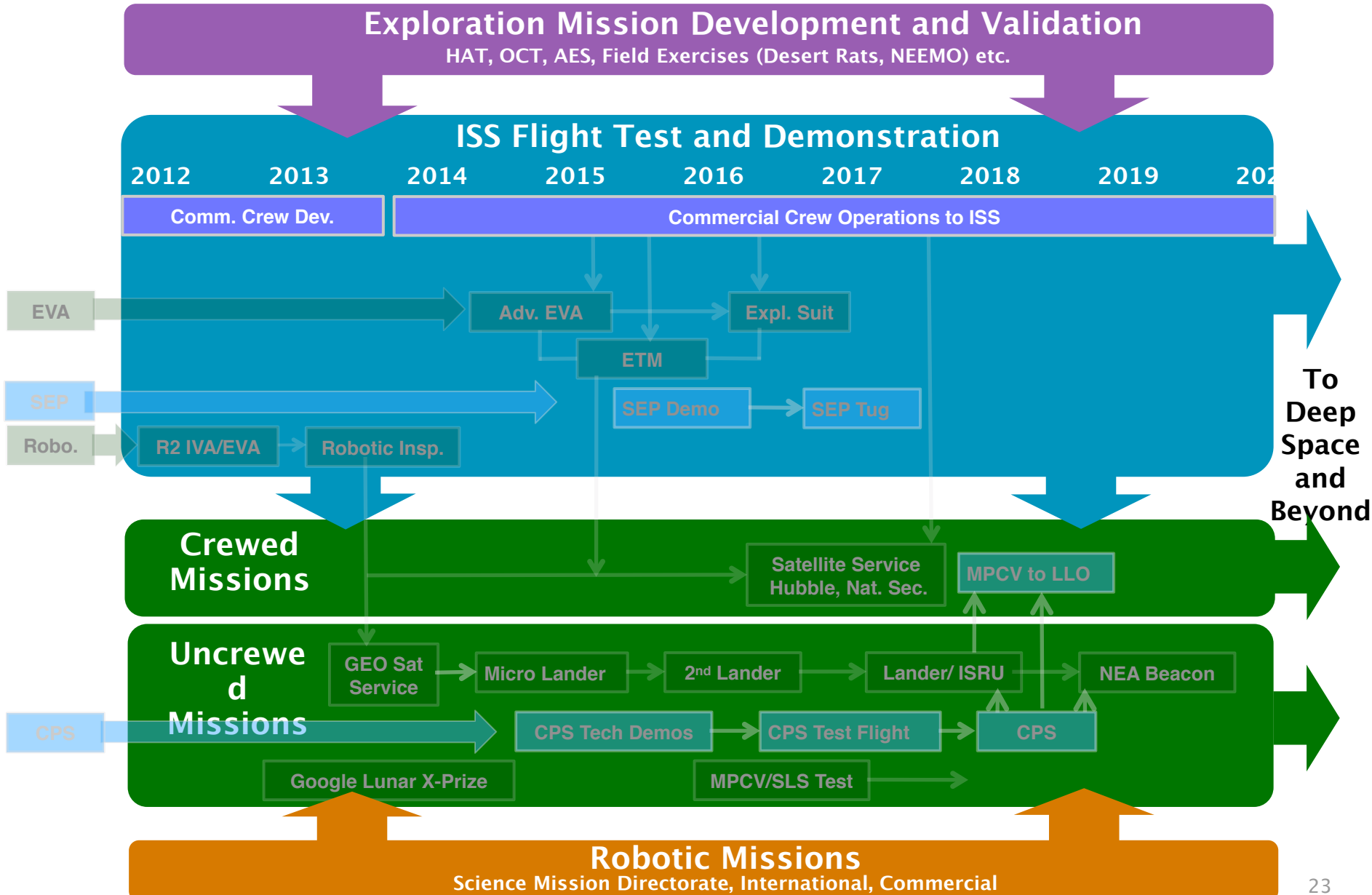
Develop Crew Elements for Deep Space at ISS



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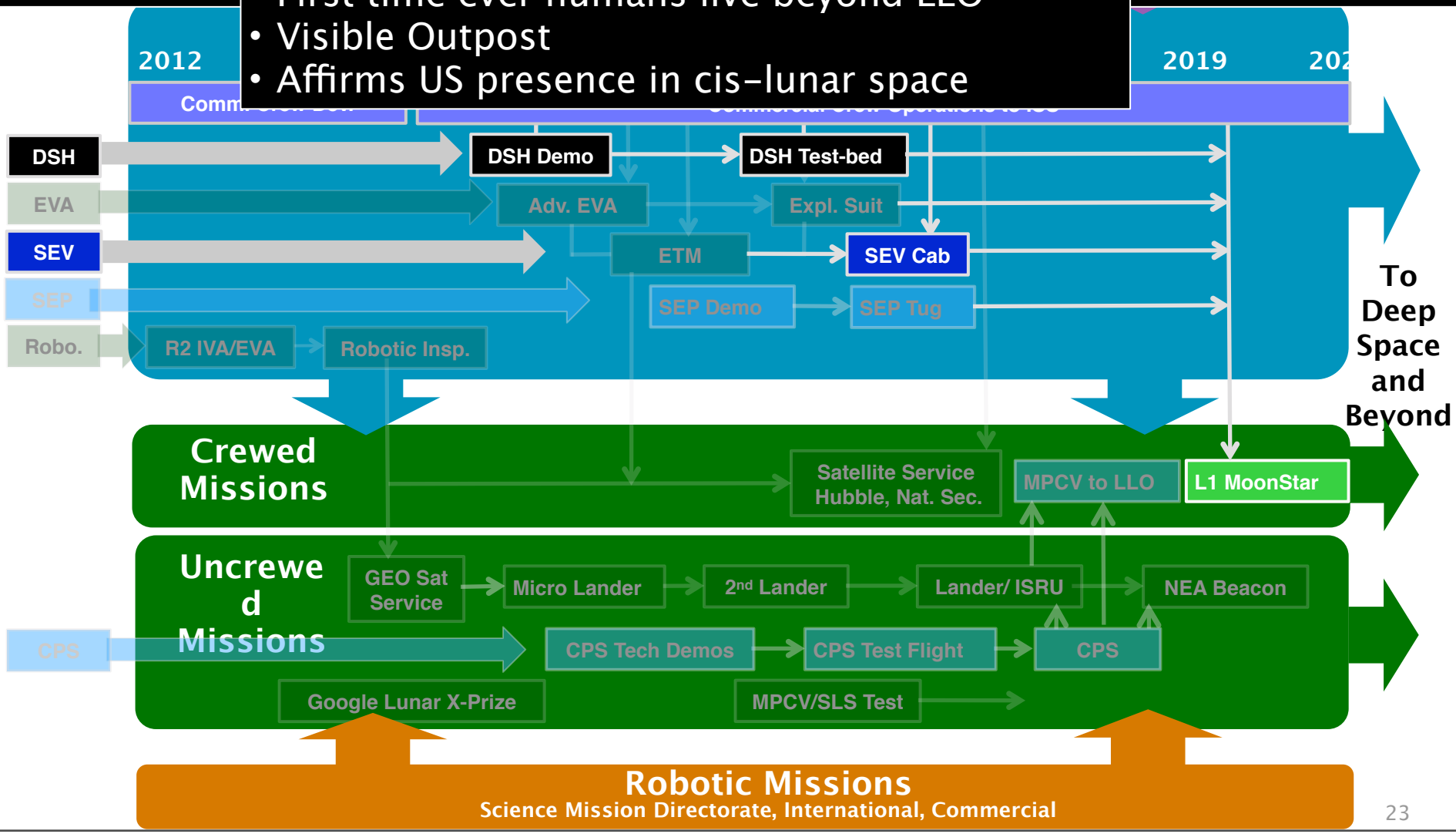
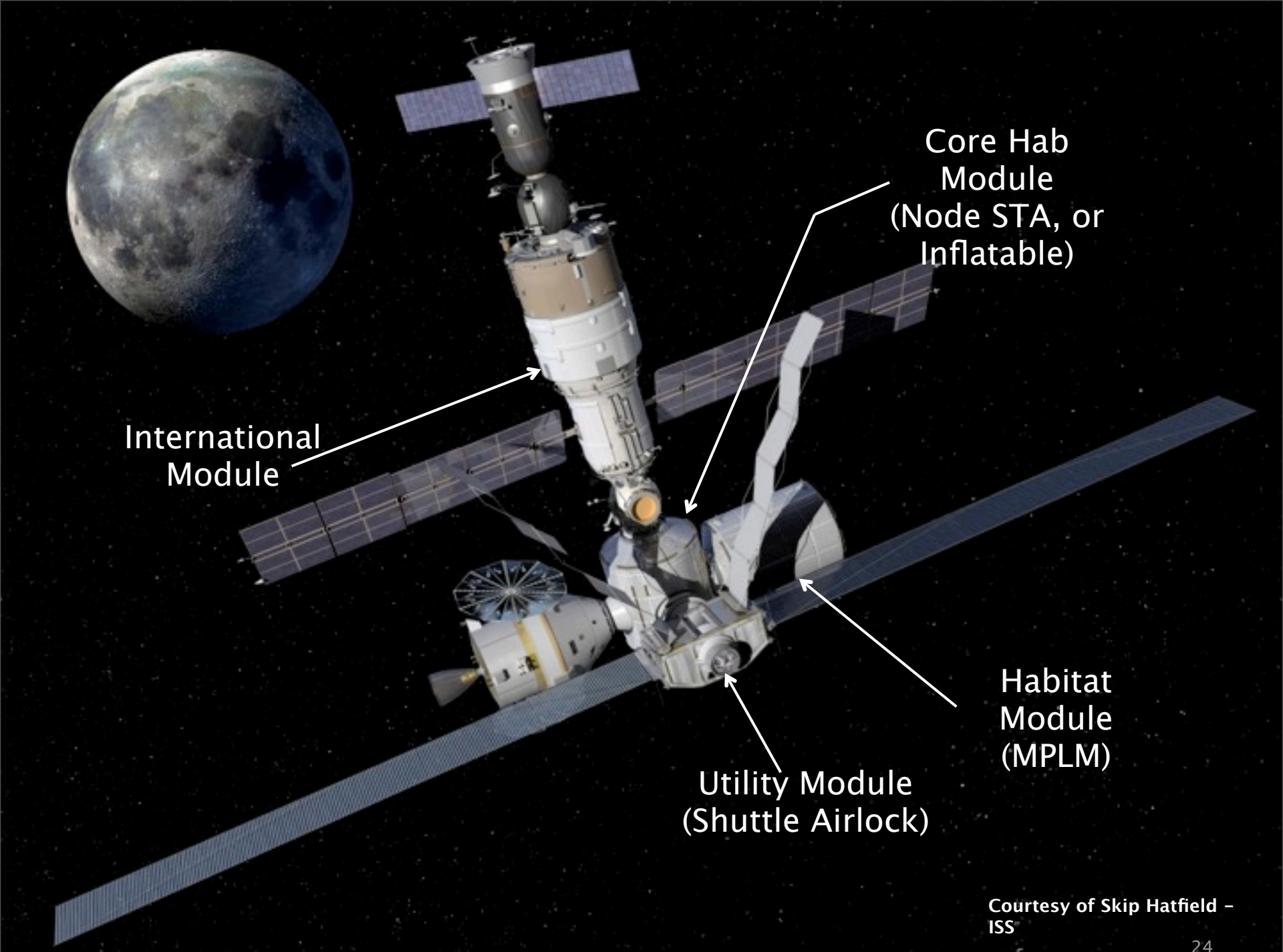
Develop Crew Elements for Deep Space at ISS

Develop crewed elements at ISS for living and working in deep space, Habitat, and Space Exploration Vehicle. After some time relocate elements to L1 or L2

- First time ever humans live beyond LEO
- Visible Outpost
- Affirms US presence in cis-lunar space

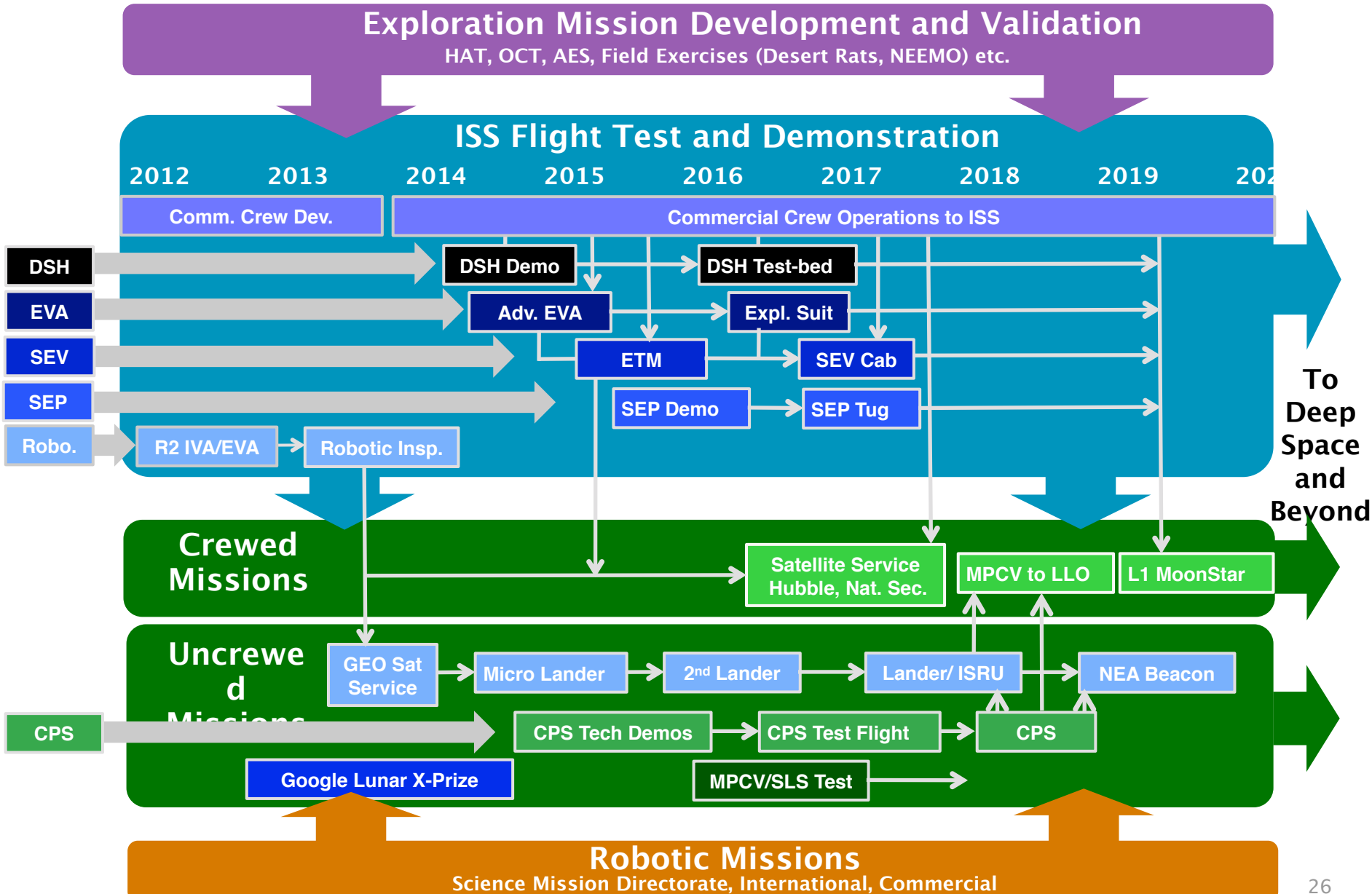




Courtesy of Skip Hatfield – ISS


MoonStar

A Cadence of Individual Activities to Open Up Deep Space



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Summary – Not a Program, Not a Destination

- **This cadence suggests a deep space capability can be slowly established without a large program – it is malleable**
  - Keep costs low with lean development, reuse/repurpose of assets already flying or in existence
  - Does not focus Agency efforts at one Center – uses across-Agency competencies
  - ISS and ISS crew support is essential
  - Leveraging commonality with existing or future activities is essential
  - IP's can productively contribute, with a big role for commercial partners
  - We must make sure each step has its own 'street appeal' to sustain public interest

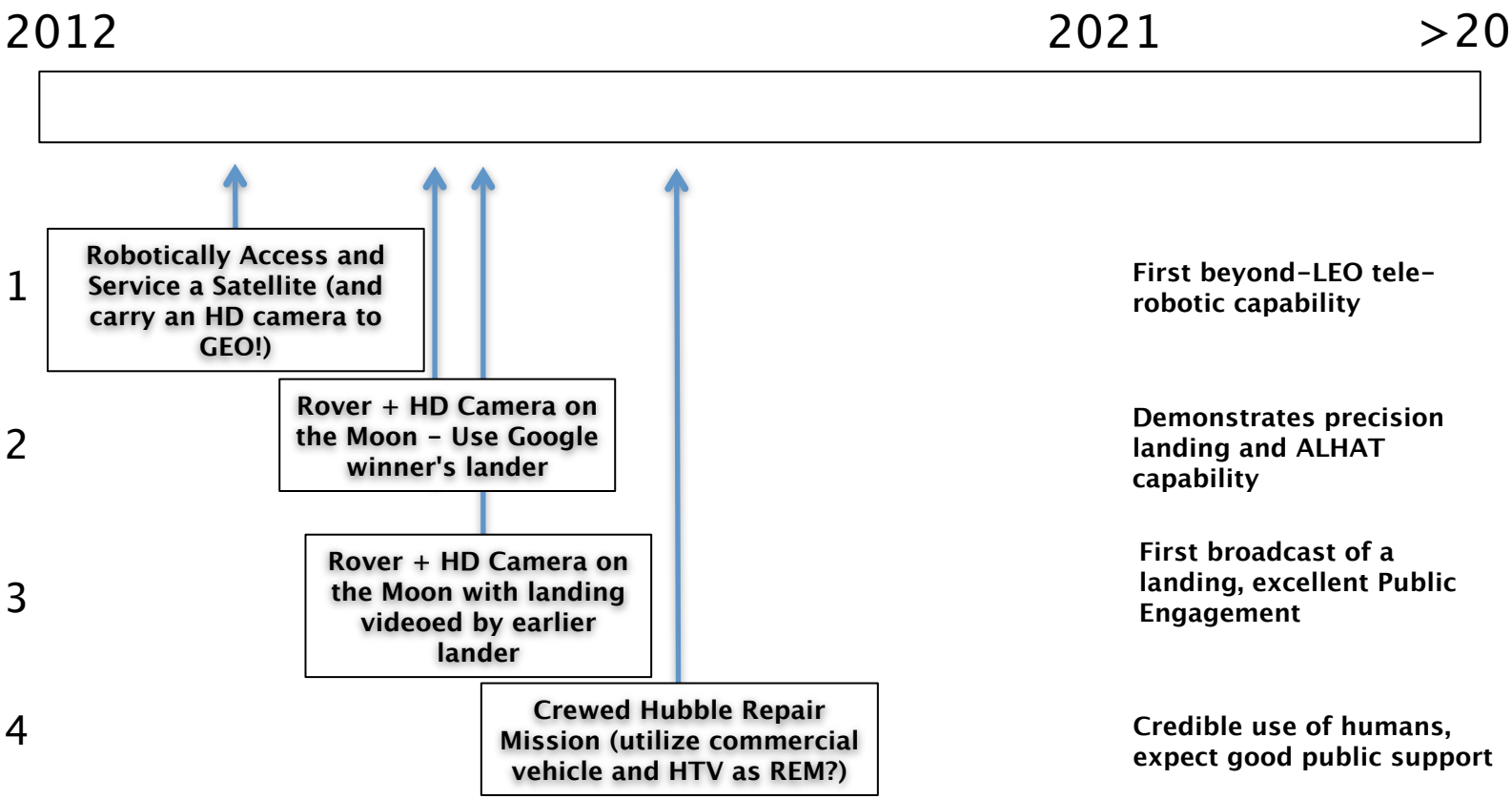
- **Next Steps – What is actually affordable?**
  - Establish available resources
  - Refine cadence and technical approach for each element – determine what is affordable
  - Better intra-agency coordination of various ongoing and disparate activities – need to integrate
  - Formalize lean development processes
  - Establish process for flight certification of repurposed or re-flown vehicles
  - Establish requirement for SIM bay on MPCV (i.e. unpressurized external cargo)

This is not a Program, it is not a Destination; it is a series of activities that aggregate to a deep space capability with US Leadership

We must make this event inconsequential:

Backup

A Cadence of Missions Toward Deep Space, Emphasizing Engaging 'Firsts'



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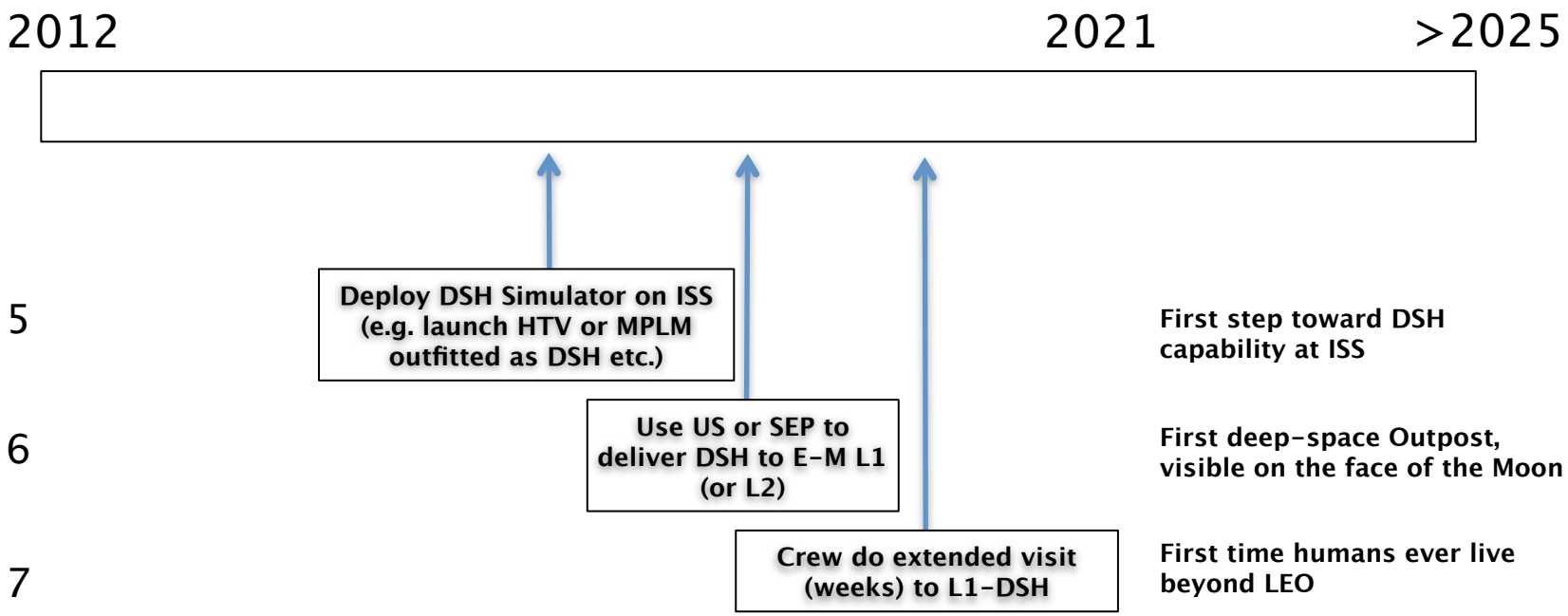
A Cadence of Missions Toward Deep Space, Emphasizing Engaging 'Firsts'



Concurrently, expand use of ISS as a Deep-Space Flight Test Center to prepare elements and then fly out beyond LEO

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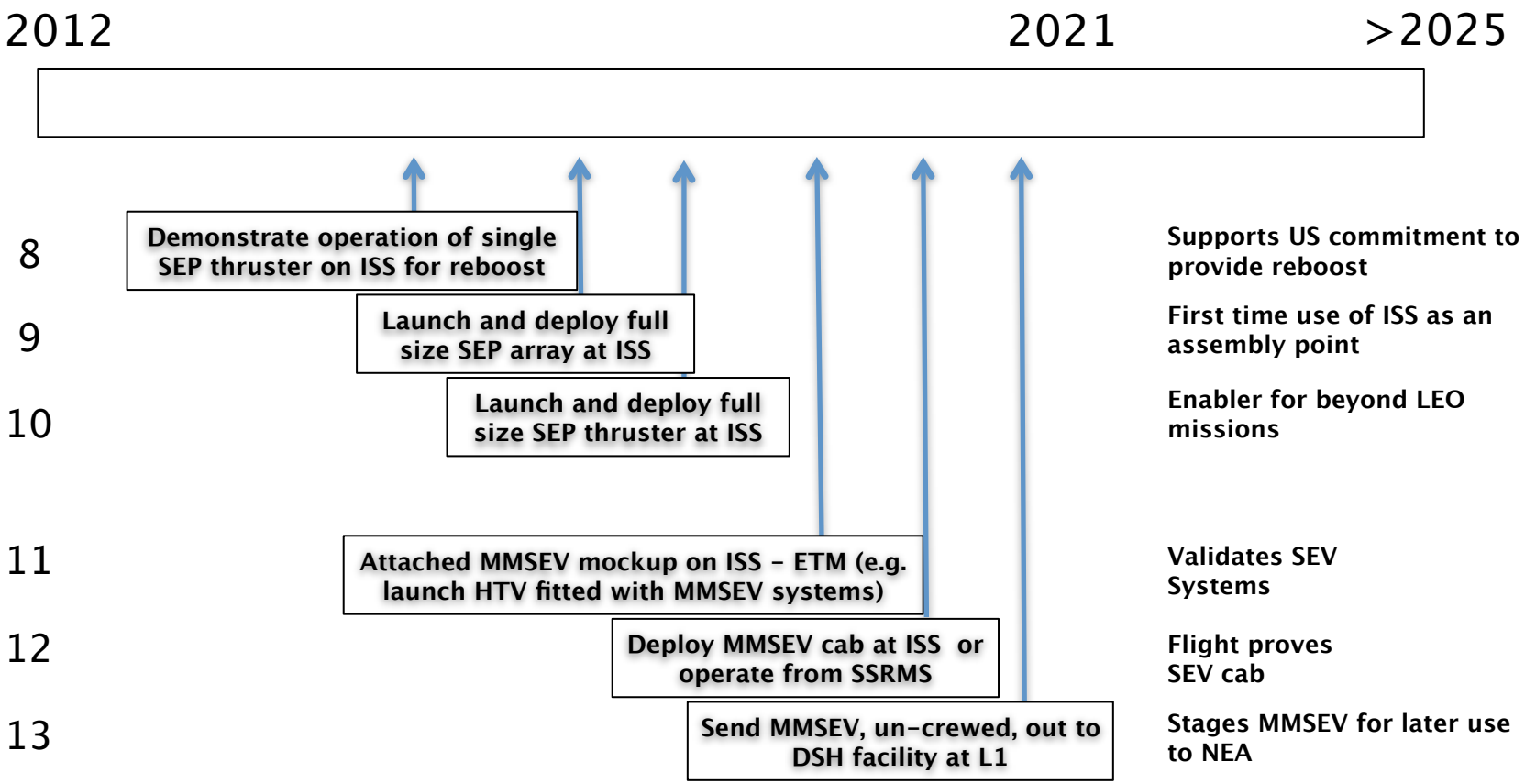
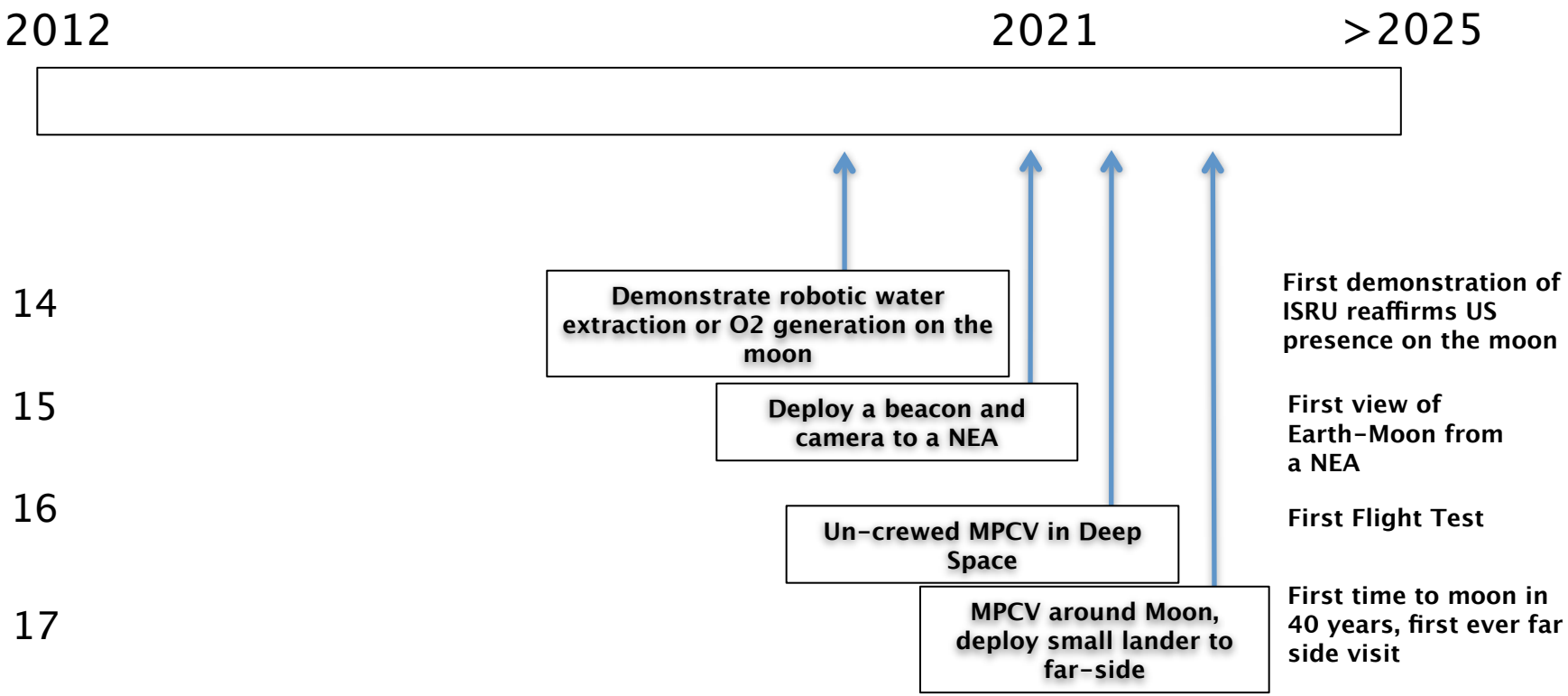


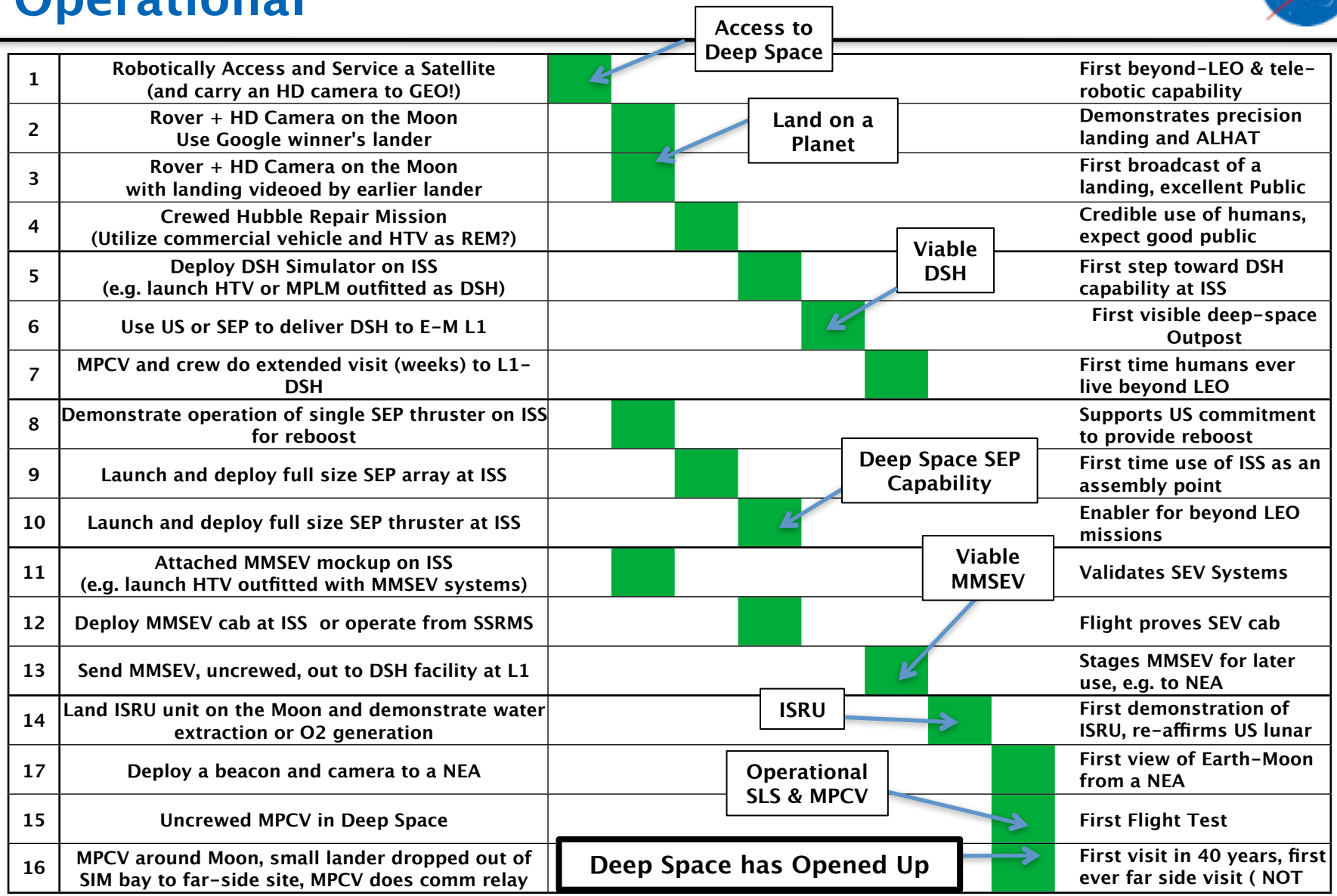
Continue to assemble and flight qualify other elements at ISS prior to sending them out

A Cadence of Missions Toward Deep Space, Emphasizing Engaging 'Firsts'



Reaffirm US as the leading presence at the moon and beyond
Bring SLS/MPCV into play and fly in deep space as soon as practical

End Result – Deep Space Elements Deployed and Operational



1	Robotically Access and Service a Satellite (and carry an HD camera to GEO!)	First beyond-LEO & tele-robotic capability
2	Rover + HD Camera on the Moon Use Google winner's lander	Demonstrates precision landing and ALHAT
3	Rover + HD Camera on the Moon with landing videoed by earlier lander	First broadcast of a landing, excellent Public
4	Crewed Hubble Repair Mission (Utilize commercial vehicle and HTV as REM?)	Credible use of humans, expect good public
5	Deploy DSH Simulator on ISS (e.g. launch HTV or MPLM outfitted as DSH)	First step toward DSH capability at ISS
6	Use US or SEP to deliver DSH to E-M L1	First visible deep-space Outpost
7	MPCV and crew do extended visit (weeks) to L1-DSH	First time humans ever live beyond LEO
8	Demonstrate operation of single SEP thruster on ISS for reboost	Supports US commitment to provide reboost
9	Launch and deploy full size SEP array at ISS	First time use of ISS as an assembly point
10	Launch and deploy full size SEP thruster at ISS	Enabler for beyond LEO missions
11	Attached MMSEV mockup on ISS (e.g. launch HTV outfitted with MMSEV systems)	Validates SEV Systems
12	Deploy MMSEV cab at ISS or operate from SSRMS	Flight proves SEV cab
13	Send MMSEV, uncrewed, out to DSH facility at L1	Stages MMSEV for later use, e.g. to NEA
14	Land ISRU unit on the Moon and demonstrate water extraction or O2 generation	First demonstration of ISRU, re-affirms US lunar
17	Deploy a beacon and camera to a NEA	First view of Earth-Moon from a NEA
15	Uncrewed MPCV in Deep Space	First Flight Test
16	MPCV around Moon, small lander dropped out of SIM bay to far-side site, MPCV does comm relay	First visit in 40 years, first ever far side visit (NOT

Currently Available Stages

- **Russia**
  - Briz-M, 4.4 klbf, Hydrazine, used on Proton
  - Block-D, 20 klbf, LOX/RP, used on Zenit
  - Soyuz 3rd stage, 67 klbf, LOX/RP
- **US**
  - Centaur, 20 – 40 klbf, LOX/LH2
  - Falcon 9 2nd stage, 140 klbf, LOX/RP
- **Europe**
  - EPS, 6 klbf, hydrazine, used on Ariane 5
  - ECS, 14.5 klbf, LOX/LH2, used on Ariane 5
- **Japan**
  - H IIB upper Stage, 30 klbf, LOX/LH2

Project Names

1. Robotically Access and Service a Satellite – **GEOview**
2. Rover + HD Camera on the Moon – **MoonWalker1**
3. Rover + HD Camera on the Moon – **MoodWalker2**
4. Uncrewed MPCV in Deep Space – **DeepSpace1**
5. MPCV-based Hubble Repair Mission – **Hubble Service Mission 5**
6. MPCV around Moon, small lander dropped out of SIM bay to far-side site, MPCV does comm relay – **FarSideLunar1**
7. Demonstrate operation of single SEP thruster on ISS for reboost – **DemoSEP**
8. Deploy Repurposed Node STA as Docking Hub to ISS – **NodeDock**
9. Deploy DSH Simulator on ISS – **LabHab**
10. Launch and deploy full size SEP unit at ISS – **SolarElectricBooster**
11. Use large SEP to deliver DSH + HD Camera to E-M L1 – **MoonStar**
12. MPCV and crew do extended visit (weeks) to L1-DSH – **SpaceCamp1**
13. Attached MMSEV mockup on ISS – **MultiMissionDemo1**
14. Deploy MMSEV and operate at ISS as free flyer or from SSRMS – **MultiMissionDemo2**
15. Send MMSEV, uncrewed, out to DSH facility at L1 –