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Booster Obsolescence and Life Extension (BOLE) for Space Launch System (SLS)

Empowering Deep Space Missions

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Introduction

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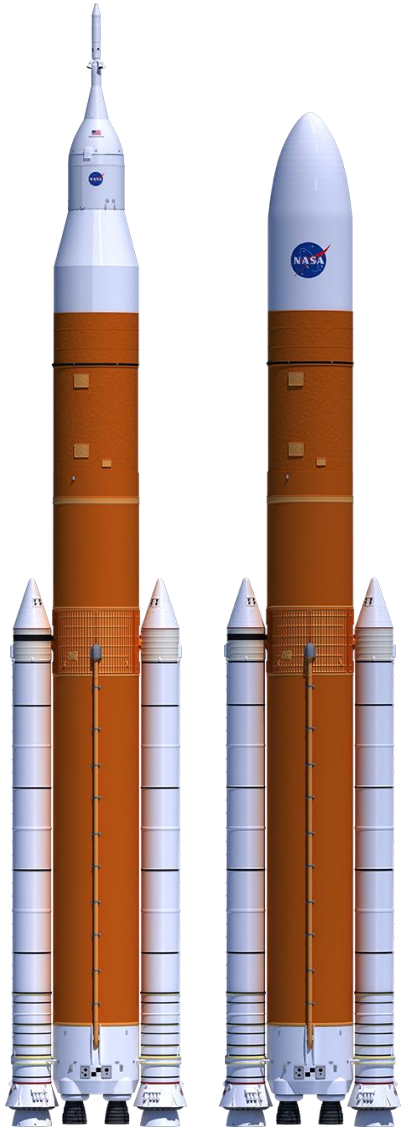
Booster Obsolescence and Life Extension (BOLE) for SLS

- Enables uninterrupted access to deep space by resolving obsolescence of legacy shuttle hardware
- Enables additional performance as part of larger Mars campaign

Planned Design Improvements

BOLE Empowers Lunar and Mars Campaigns



Approach to Moon and Mars Exploration

SLS is a keystone of Moon and Mars Exploration plan

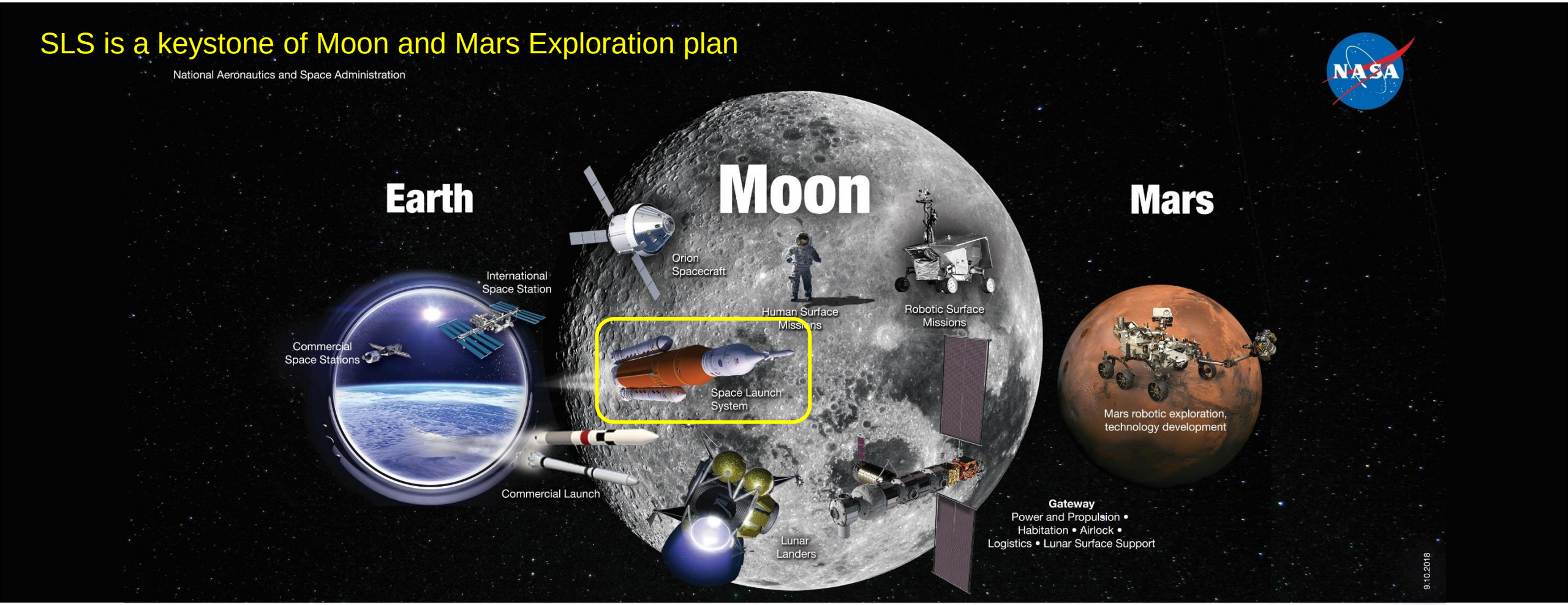


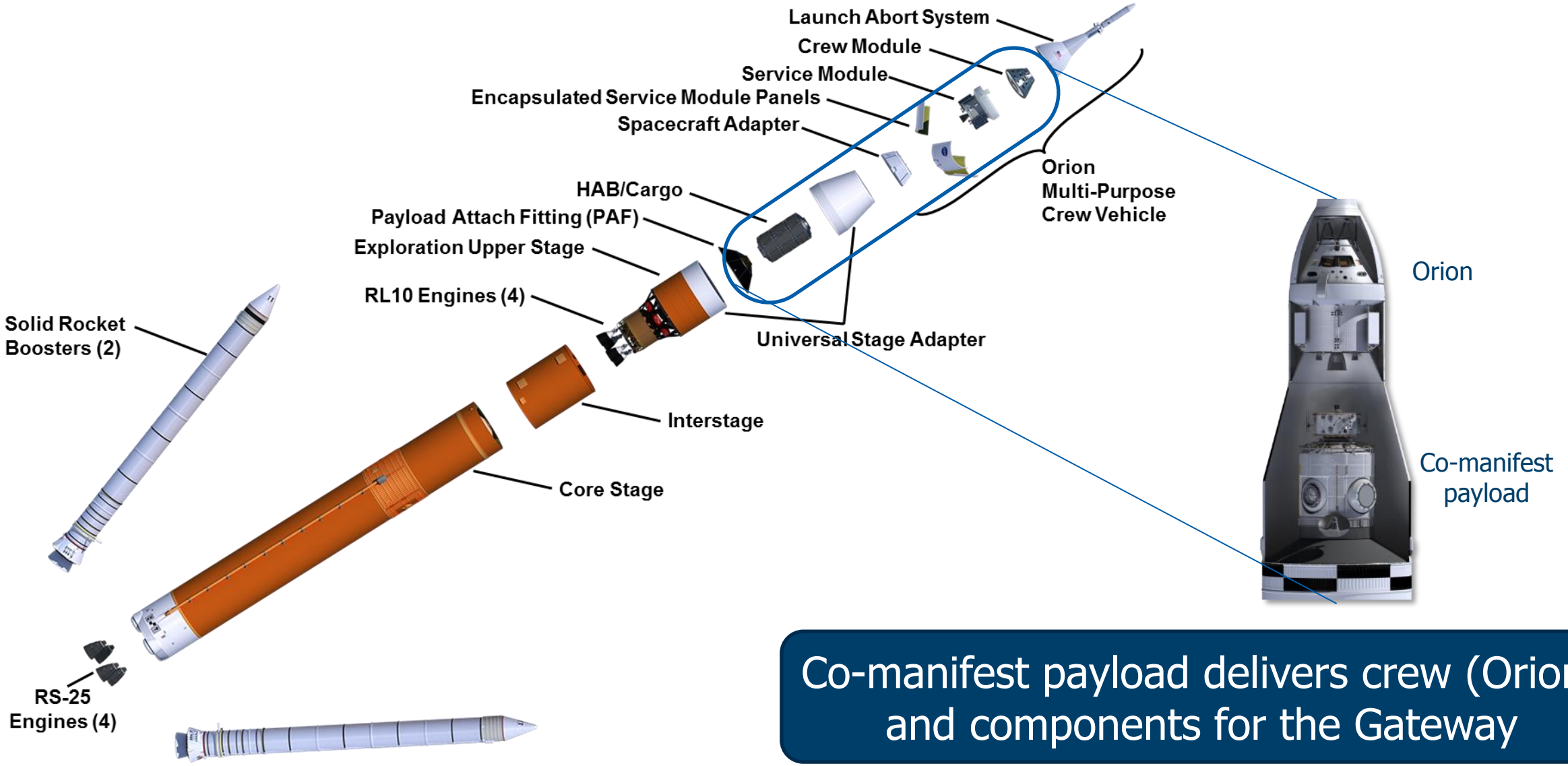
Image courtesy of NASA

America Will Lead
Fly Astronauts on American Spacecraft
Develop New Commercial Space Stations

America Will Lead
Fly Astronauts Around the Moon
Establish the First Human Outpost Around the Moon
Return American Astronauts to the Moon for a Sustained Campaign of Exploration and Utilization

America Will Lead
Return the First Scientific Collection from Mars
Practice a Round-trip Leading to Humans to Mars

SLS Block 1B – Expanded View



Co-manifest payload delivers crew (Orion) and components for the Gateway

BOLE Design Changes Overview

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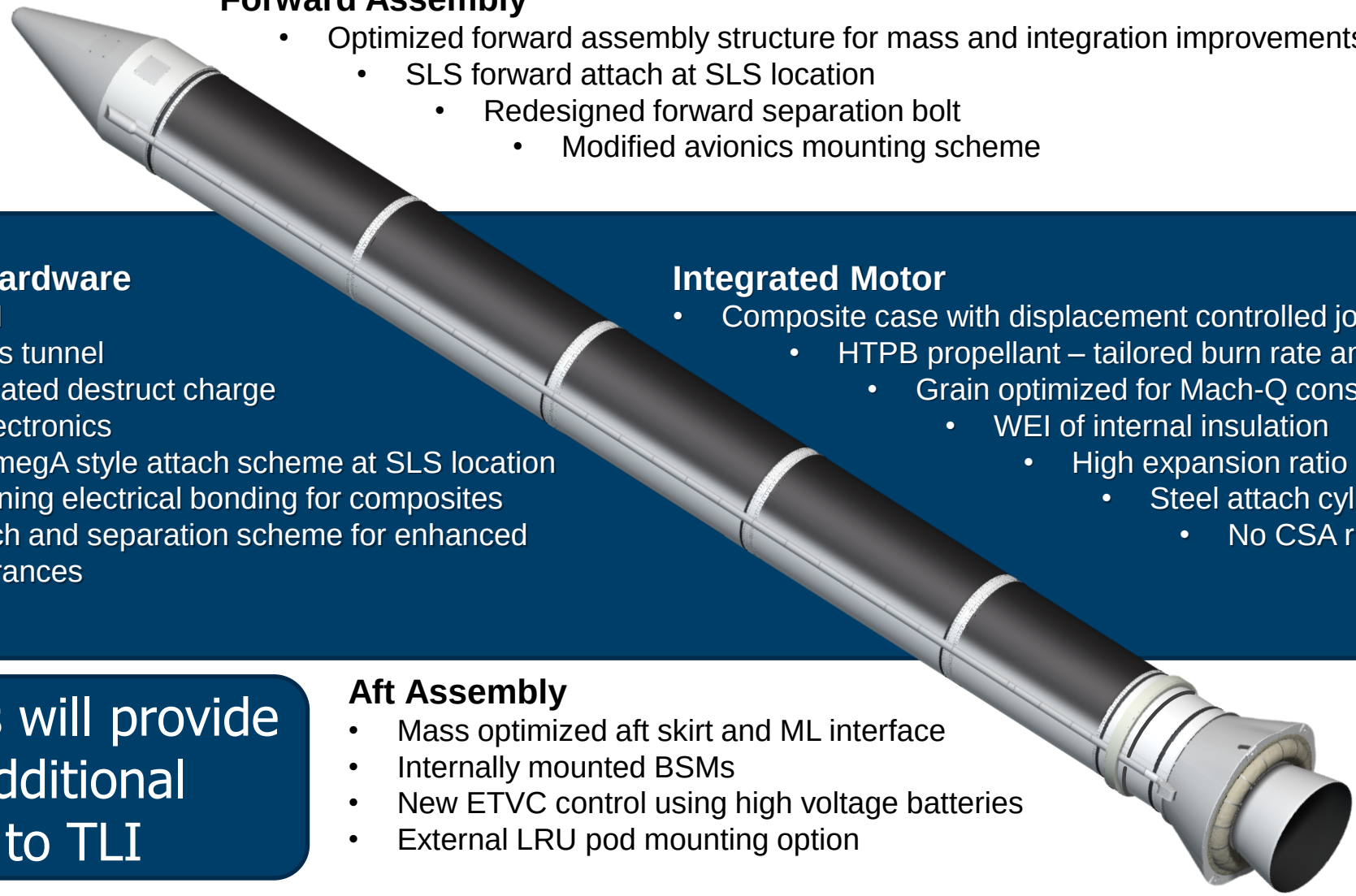
Forward Assembly

- Optimized forward assembly structure for mass and integration improvements
  - SLS forward attach at SLS location
    - Redesigned forward separation bolt
      - Modified avionics mounting scheme



Integration Hardware

- SLS-like DFI
- New systems tunnel
- Newly integrated destruct charge
- SLS FSS electronics
- Titan and OmegA style attach scheme at SLS location
- Indirect lightning electrical bonding for composites
- Proven attach and separation scheme for enhanced vehicle clearances

Integrated Motor

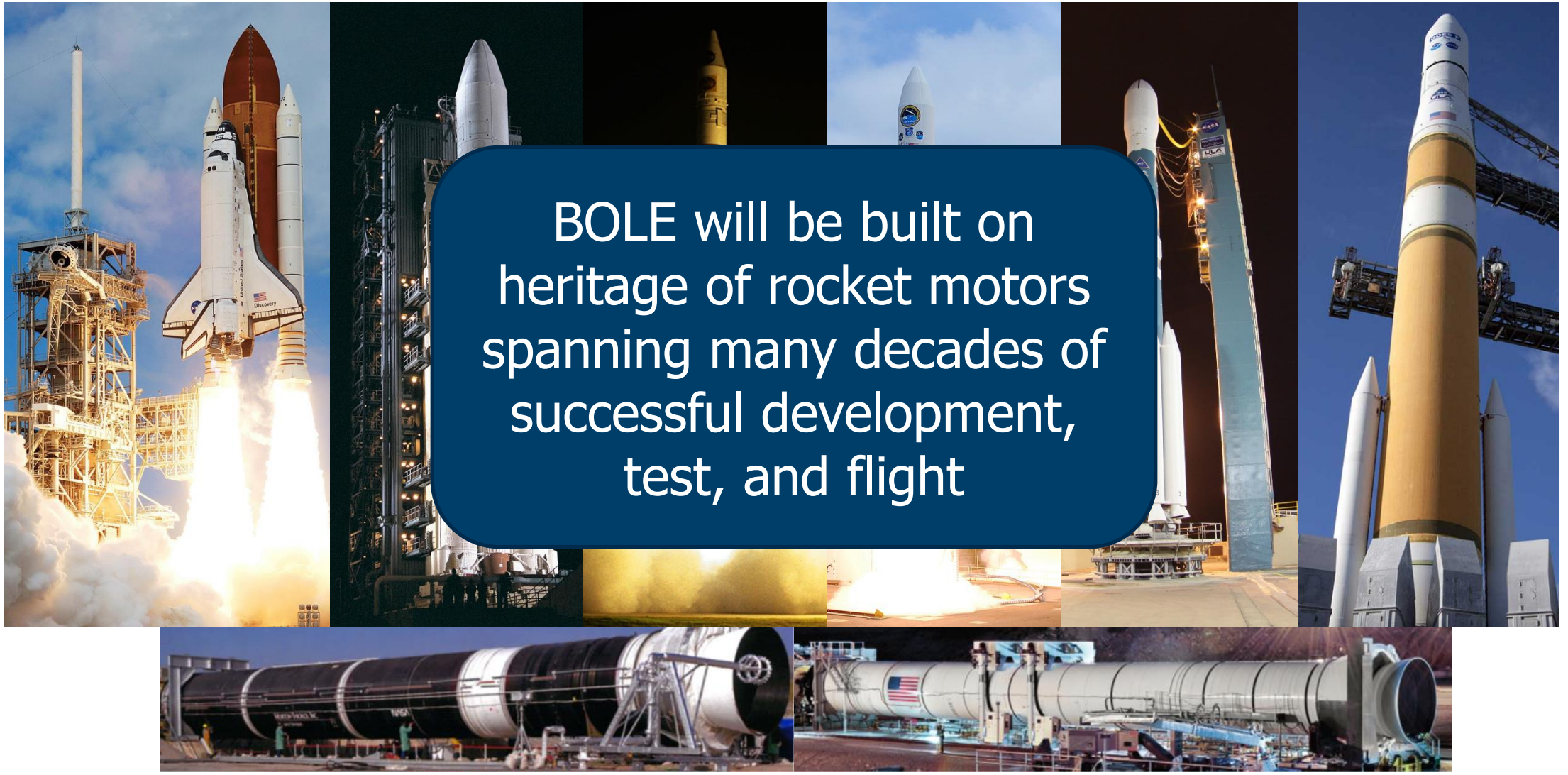
- Composite case with displacement controlled joints
  - HTPB propellant – tailored burn rate and grain design
    - Grain optimized for Mach-Q constraint
      - WEI of internal insulation
        - High expansion ratio nozzle and exit cone
          - Steel attach cylinder and domes
            - No CSA ring

BOLE changes will provide 3 mT of additional payload to TLI

Aft Assembly

- Mass optimized aft skirt and ML interface
- Internally mounted BSMs
- New ETVC control using high voltage batteries
- External LRU pod mounting option

BOLE Design Leverages Heritage and Current Production Vehicles

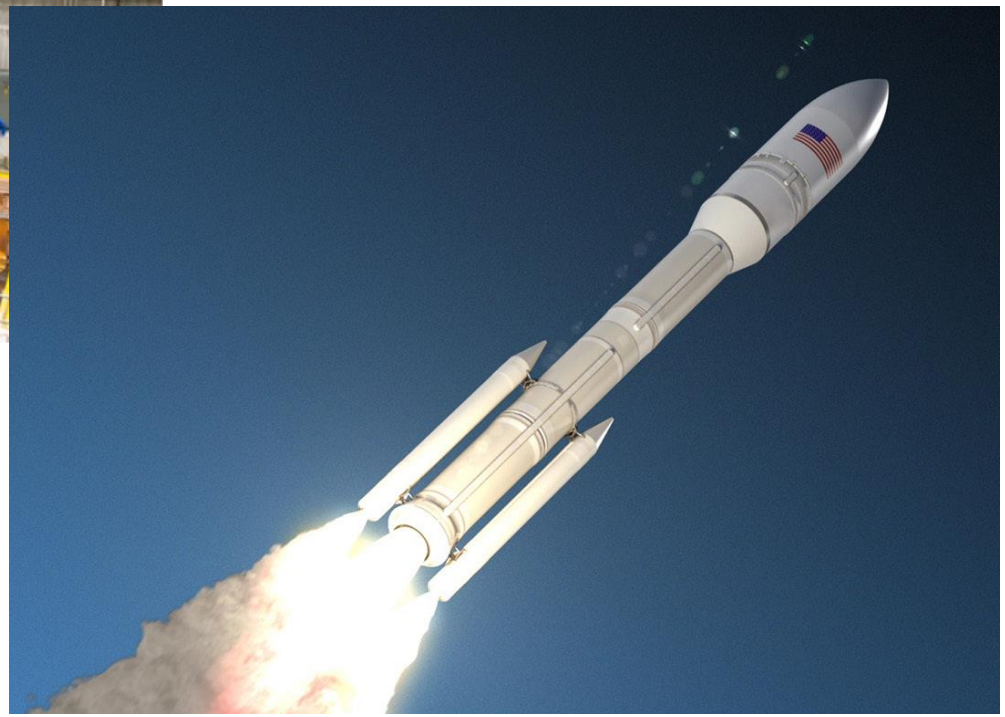


Shuttle image from https://en.wikipedia.org/wiki/Space_Shuttle#/media/File:STS120LaunchHiRes-edit1.jpg
Titan image from https://en.wikipedia.org/wiki/Titan_IV#/media/File:Titan4B_on_Launch_Complex_40.jpg
Delta II image from https://www.flickr.com/photos/ulalaunch/39206526565/in/album-72157663399219447/

RSRMV image from http://www.northropgrumman.com/Capabilities/SLSSolidRocketBoosters/Documents/SLS_Booster_Factsheet.pdf
Delta IV image from https://mobile.arc.nasa.gov/public/iexplore/missions/pages/lsp/MobileWebsite/SubPages/DeltaIV.html
Athena II image from http://solarviews.com/cap/craft/lunpros2.htm
Minotaur IV image from https://en.wikipedia.org/wiki/Minotaur_IV#/media/File:Minotaur-4-Lite_HTV-2a_2.jpg

BOLE Design Leverages Heritage and Current Production Vehicles

BOLE leverages significant recent investments in OmegA™



OmegA images taken from http://www.northropgrumman.com/Capabilities/OmegA/Documents/CBS_FactSheet.pdf

SLS Configuration Evolution

Block 1
Crew

LAS
Orion
ICPS

EUS

EM-1
EM-2

Block 1B
Crew

LAS
Orion
EUS

EM-3

RS-25 New

Block 1B
Crew

LAS
Orion
EUS

Gateway

BOLE

Block 1B+
Crew

LAS
Orion
EUS

Gateway
Lunar Sample Return
Lunar Sortie
Phobos
Mars

BOLE enhances the evolutionary path of SLS

sets of
ning from
After 8

Cargo

Block 1
Cargo

D-IVH Fairing
(5.1 m x 19 m)
ICPS

Europa

EUS

RS-25 New

Cargo

Short Fairing
EUS

Europa
Gateway

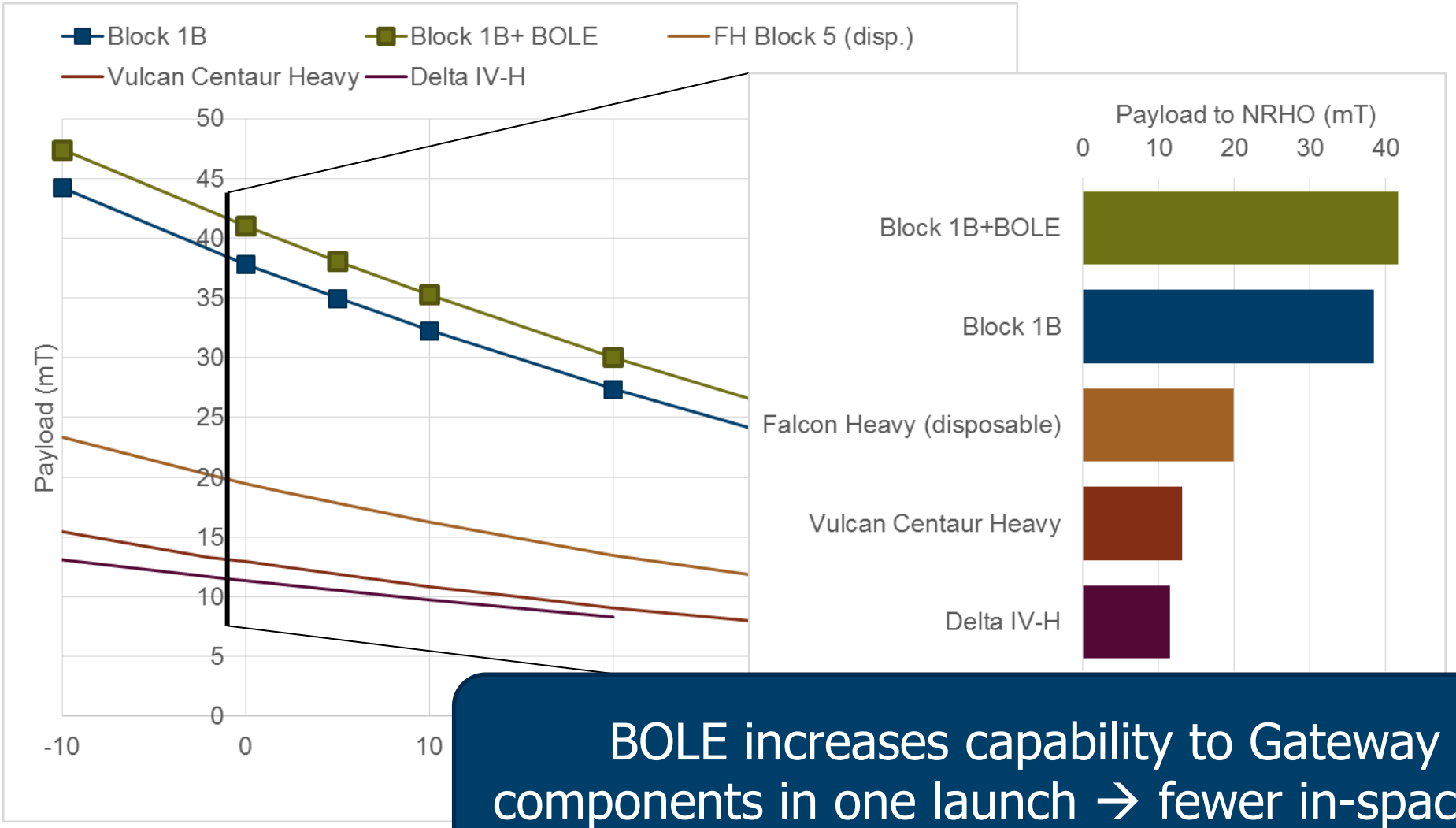
BOLE

Block 1B+
Cargo

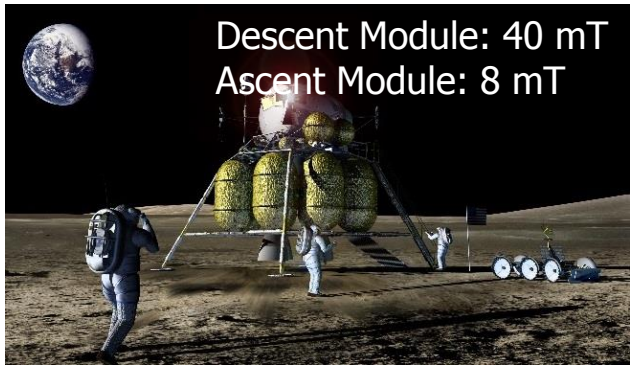
Long Fairing
EUS

Gateway
Lunar Lander
High C3 Science
Phobos
Mars

BOLE Empowers Future Exploration Missions



Possible payloads



Deep Space Transport (DST)
Habitat: 28 mT (empty)
DST Power & Propulsion Module: 25 mT (empty)

BOLE increases capability to Gateway and allows larger components in one launch → fewer in-space assembly operations

Gateway image from: https://www.nasa.gov/sites/default/files/thumbnails/image/
Lunar lander image from: https://www.nasa.gov/images/content/163697main_land
Lander design and image from: Boeing Corporation, IEEE 2018_2100_8.0106
DST hab from: AIAA-2018-5143
DST PPE from: AIAA-2018-5141

BOLE Empowers Future Science Missions

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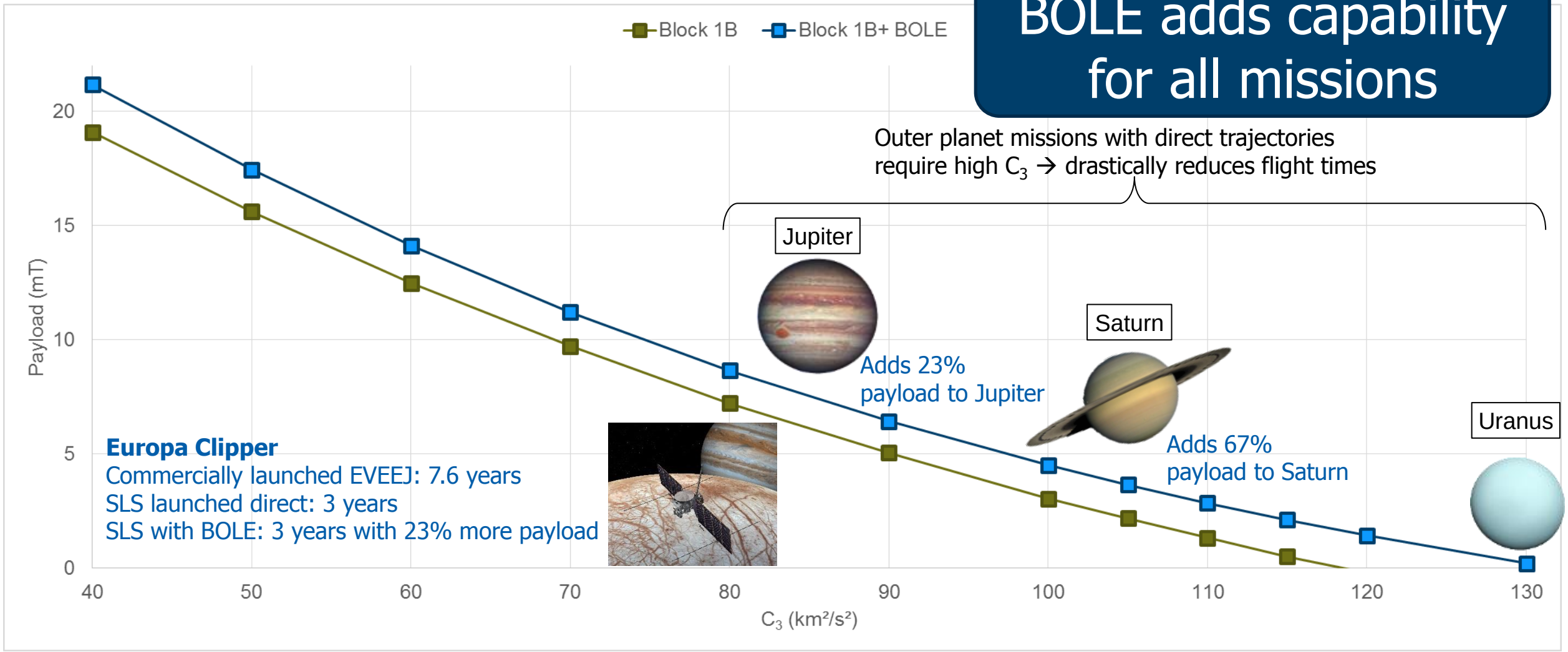
BOLE adds capability for all missions



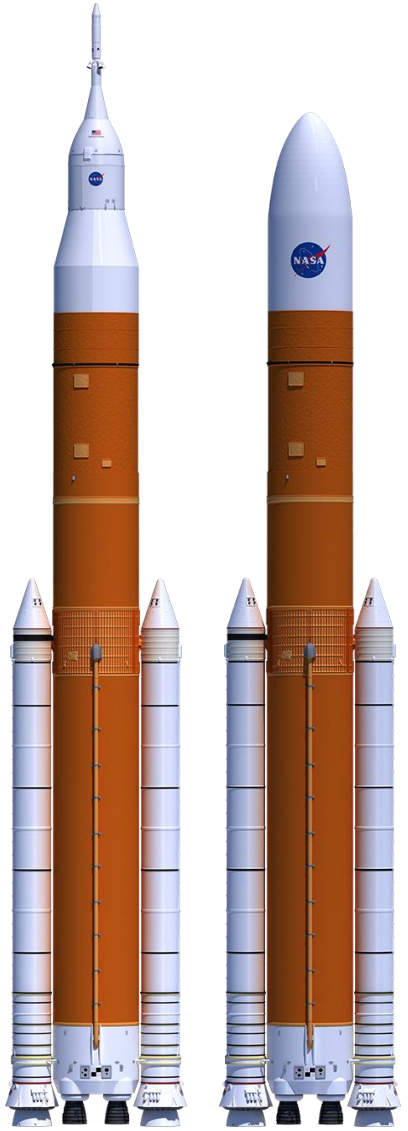
Jupiter image from: https://www.nasa.gov/sites/default/files/thumbnails/image/jupapr3color-jd-170304_0.png
Saturn image from: https://www.nasa.gov/sites/default/files/images/365640main_PIA11141_full.jpg
Uranus image from: https://www.nasa.gov/sites/default/files/thumbnails/image/pia18182-16.jpg
Europa Clipper image from: https://www.jpl.nasa.gov/missions/web/europa_full.jpg

Conclusion

BOLE program extends the life of the SLS vehicle architecture beyond the existing inventory of shuttle hardware

BOLE leverages Northrop Grumman's current investments in commercial markets for OmegA and provides significant cost and technological synergies

The BOLE booster is one additional step on the SLS evolution path, making it an ever more capable heavy lift launch vehicle that will propel us to the moon, Mars and beyond



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