Mobile Launcher 2

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The Artemis Campaign

The Artemis Campaign

Learning from Apollo, the Artemis Generation will return to the Moon to further scientific discovery, economic benefits, and inspiration for a new generation of exploration.

- Artemis Accords - International Mission
  - 33 countries have signed onto principles for a safe, peaceful, and prosperous future.
- American Leadership - National Mission
- Uniting government, industry, and academia to support the Moon to Mars Mission.

Artemis Missions Timeline

Missions planned for ML1

- **Artemis I** – launched on November 16, 2022
- **Artemis II** – September 2025
  - First crewed launch
- **Artemis III** – September 2026
  - Planned lunar landing

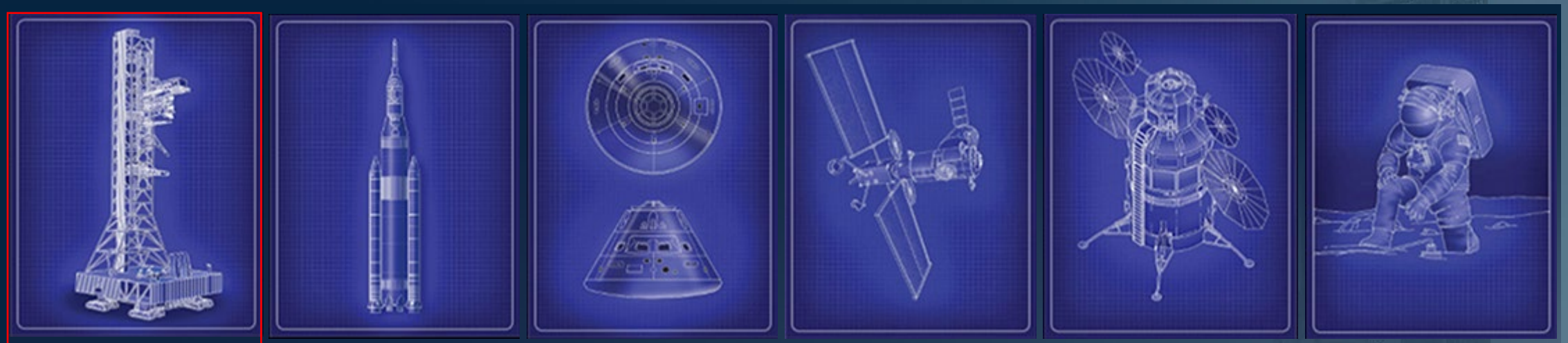
Missions to be launched by ML2

- **Artemis IV** – Delivery of I-HAB to Gateway
  - First use of SLS Block 1B Orion rocket
- **Artemis V** – Delivery of ESPIRIT and Canadarm
- **Artemis VII** – Delivery of Lunar Cruiser
- **Artemis VIII** – Delivery of Surface Habitat

Artemis I launch on November 16, 2022.

Photo courtesy of NASA.

NASA's Exploration Ground Systems



Exploration Ground Systems | Space Launch System | Orion | Gateway | Lunar Landers | Artemis Generation Spacesuits

- **Exploration Ground Systems (EGS),** based at NASA's Kennedy Space Center in Florida, develops and operates the systems and facilities needed to process and launch rockets and spacecraft for NASA's Artemis missions.
- EGS is one of six Artemis Programs.
- The EGS scope includes the development and maintenance of NASA's Mobile Launchers.

The Mobile Launchers

The Crawler – What Makes the Mobile Launcher "Mobile"

Crawler Dimensions

Size – *131 ft long, 114 ft wide*

Height – *min 20 ft, max 26 ft*

Speed – *1 mph loaded or 2 mph unloaded*

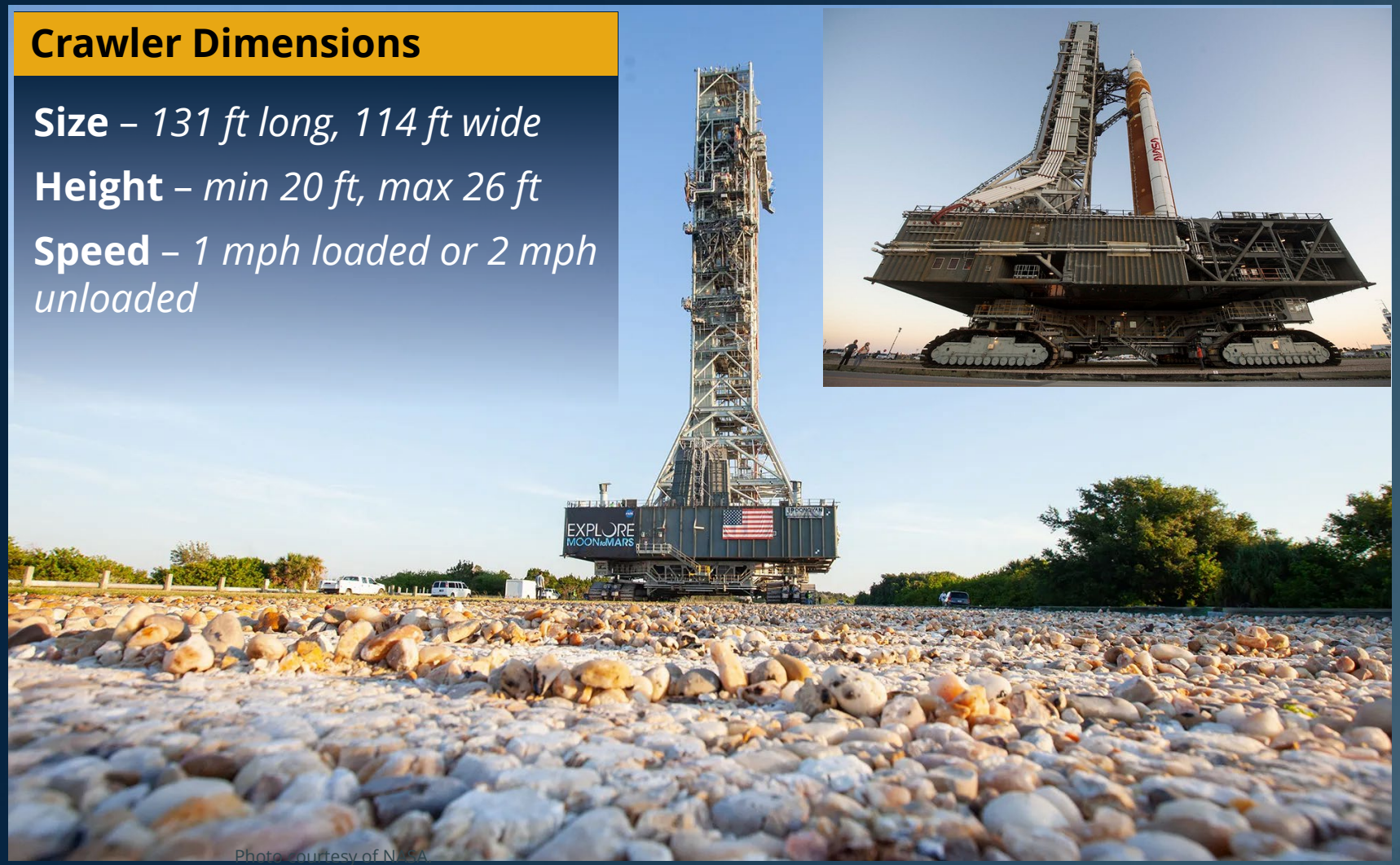


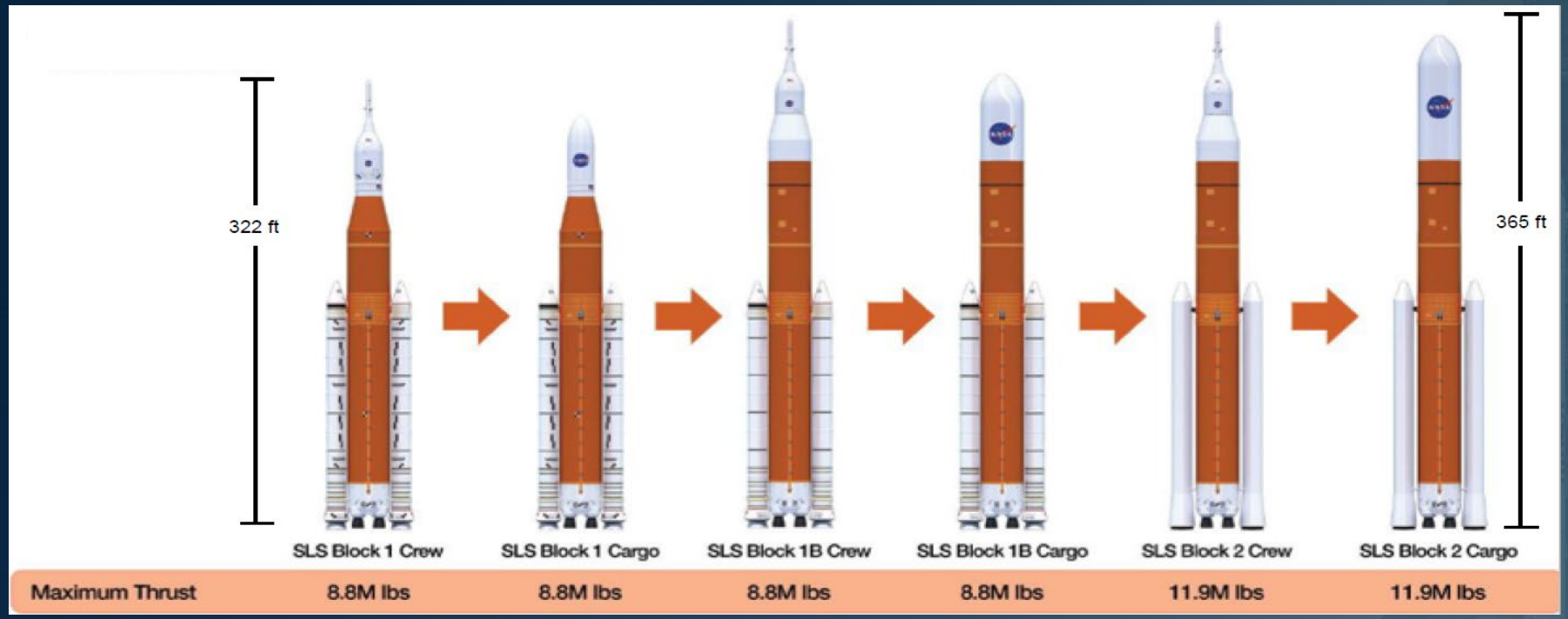
Photo courtesy of NASA.

Photo courtesy of NASA.

- In the 1960's NASA built two crawler-transporters to carry rockets and spacecrafts between the Vehicle Assembly Building, or VAB, and launch pads.
- The crawlers reside at Kennedy Space Center where they travel on a 4.2 mile-long road paved with special river rocks from Alabama.

ML2 Supports Space Launch System (SLS) Rocket Evolution

- As the Artemis Campaign continues, the SLS Rocket will be advanced to carry equipment for Gateway.
- ML2 is being built to accommodate this increase in size and other capabilities.



Artemis I – III	Artemis IV and beyond
ML1	ML2

ML1 and ML2 Comparison

Mobile Launcher 1

- **Total height above ground:** 380 feet
- **Tower:** about 355 feet tall, 40 feet square
- **Approximate weight:** 10.5 million pounds

Mobile Launcher 2

Total height above ground: 402 feet

Tower: about 377 feet tall, 40 feet x 50 feet square

Approximate weight: 12.4 million pounds


BECHTEL
No Ordinary Construction Project

Project Overview

ML2 is the first project Bechtel is completing for NASA in more than 40 years

- **Initial Award**: July 2019
- **Contract Completion**: May 2026
- **Total Contract**: $1,049M
- **Contract Type**: Cost Plus Award Fee
- **365+** Bechtel employees supporting the project
- 450+ craft at peak
- 7 local unions

Five Work Sites at Kennedy Space Center

Harnessing Extremes

Tower Characteristics

- 35 stories tall
- Will withstand >2,200° F temperatures
- Will interface with VAB and Launch Pad 39B

ML2 Dimensions

Weight – *12.4M lbs.*
Height – *377 ft*
Base – *160 ft x 135 ft x 25 ft*
Tower – *40 f x 50 ft x 352 ft*

Launch Environment

Temperatures > *2,200° F*
Blast Pressures > *130 psi*
Acoustic Loading > *2 psi*

Block 1B/2 Rockets

Wet Load – *5.75M lbs. – 6M lbs.*
Cryogenic – *2M lbs.(LH_2, LO_2), -423° F*
Thrust – *8.9M lbs. – 9.5M lbs.*
Speed – *24,500 mph*

Special Design Considerations: Staying Under the Weight Limit

NASA has a strict weight requirement for ML2 due to constraints on the Crawler.

The Crawler and its specialized "Crawler Way" path used to transport the mobile launcher to the launch pad has weight restrictions.

Lessons Learned from ML1:

- Weight of ML1 was 1 million lbs. heavier than expected
- Need to improve weight tracking system in design and construction

Bechtel's Task:

- Keep ML2 under 12,867,700 lbs., currently within 2.83% margin
- Maintain an efficient structural design
- Create weight validation dashboard to track weight during design (weight fully modeled)
- Use load cells during construction to give real-time weight measurements

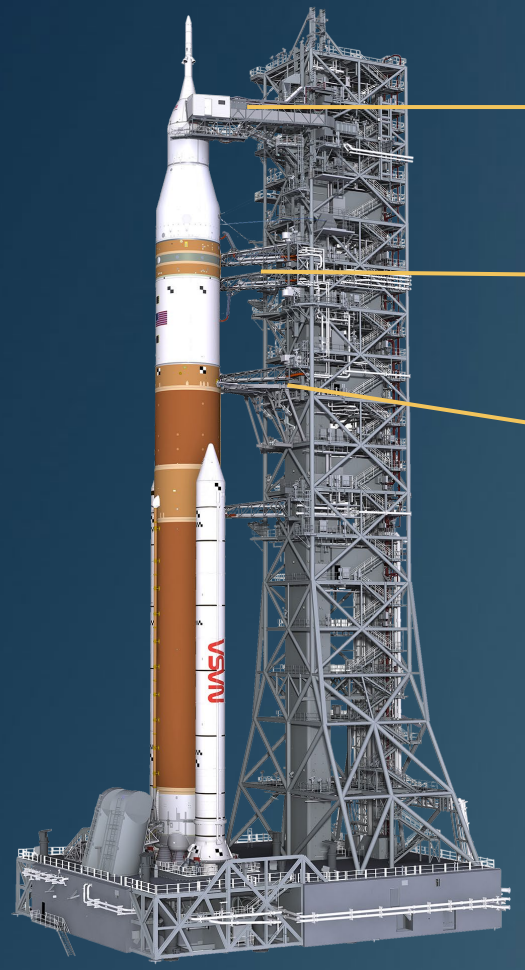
Special Design Considerations: Tower Lean

Umbilicals are key connection points between the rocket and the tower.

Crew Access Arm – Connection between Orion and the launcher.

Vehicle Dampener – Controls movement of the rocket during pad rollout and pad stay, accounting for transport vibrations and weather.

Vehicle Stabilizer – Keeps the rocket upright during assembly, rollout, and launch pad stay.



Tower Lean

- Must keep the tower vertical when the umbilicals swing out.
- Tolerances between the rocket and the umbilicals vary, with some tolerances as tight as 1/8th of an inch.

Special Design Considerations: Emergency Egress System

Emergency Egress System

- NASA system designed to carry astronauts from the Orion capsule on the Crew Access level about 317 feet above the ground to a safe exit point on the launch pad.
- ML2 team is designing and building the platform and anchor points on the mobile launcher.
  - Crew Access Level designed to accommodate astronauts in full space suits and their equipment.
  - Will hold 4 emergency egress baskets.

Crew emergency egress basket.
Photo courtesy of NASA

Special Design Considerations: Human Factors (Safety and Maintainability)

- Mobile Launcher 2 is being designed with a particular focus on human factors and making the mobile launcher safe to use.
- Through careful and intentional analysis and redesign, the team has resolved issues present in ML1, such as:
  - **Confined Spaces** – Resolving access and ventilation issues to allow for maintenance in between launches.
  - **Tripping Hazards** – Egresses are being planned without trip hazards or designed with careful marking of obstacles.
  - **Designing for Crew Access** – ML2 is being designed so it is navigable with astronauts in their full space suits.

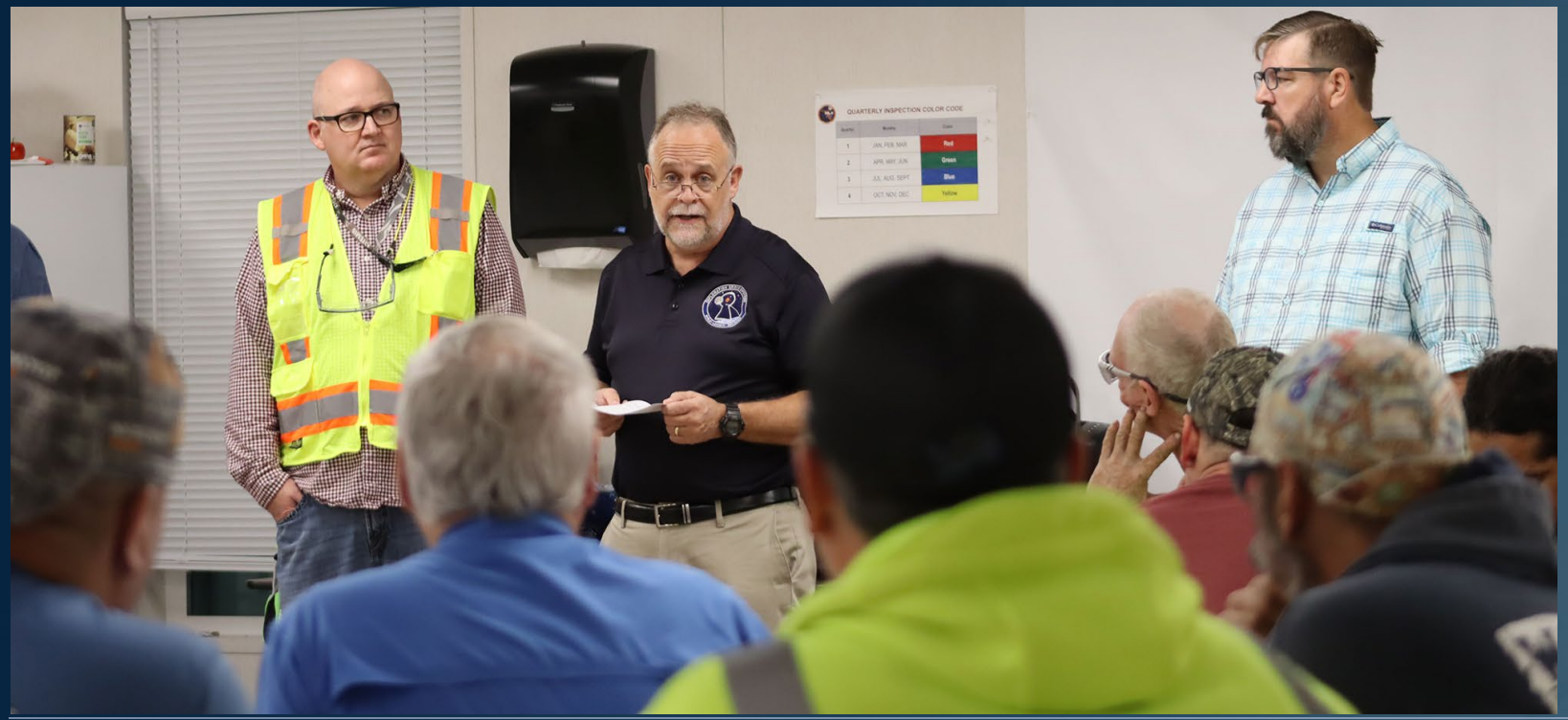
Bechtel and NASA integrated team

Integral to Build Plan

Safety is a core value

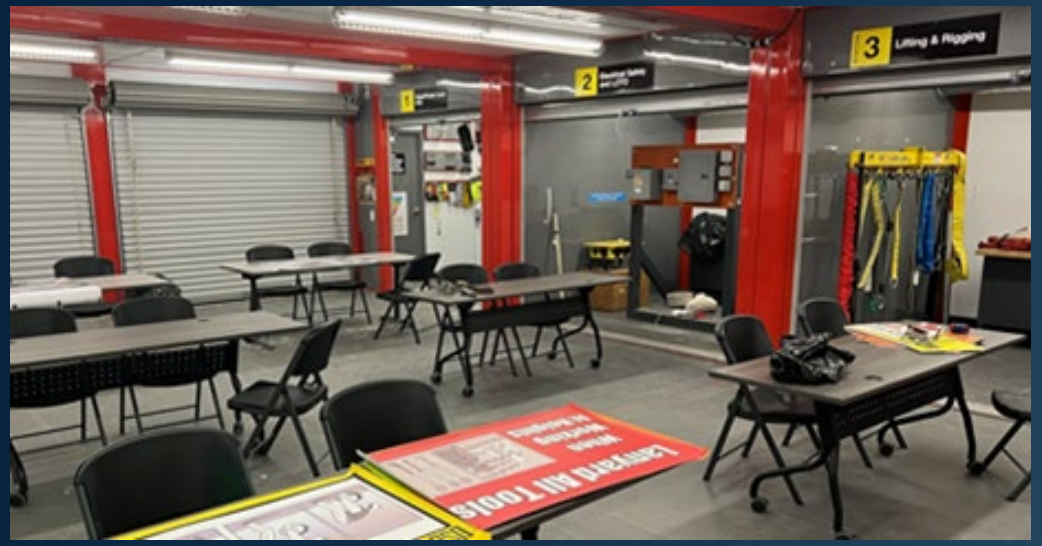
Every colleague has the power and authority to raise safety concerns and stop work.

Safety stand downs, pre and post safety briefings for each work package, and job hazard analyses core to an integrated safety program.



Bechtel and NASA leadership work together to perform safety engagements.

Safety Learning



Setting a strong foundation by:

- Conducting a mandatory site-specific safety orientation to communicate the project safety culture and expectations.
- 90-Day Lookahead to identify upcoming high-risk activities and plan mitigation control measures.

Bechtel Hazard School with multiple booths to demonstrate:

- Proper scaffolding usage
- Project rigging standards
- Lock out/tag out (LOTO) requirements
- Dropped object and fall prevention

Systems Integration: Seamless Interaction with NASA

Systems Engineering

- NASA design requirements to support spaceflight and launch safety, such as:
  - Cryogenic systems
  - Hypergolic chemistry
  - Extreme corrosive environments

Government Furnished Elements

- Elements designed by NASA, procured and installed by Bechtel.
  - Vehicle Dampening System, Emergency Egress System, Tail Service Mast Umbilical
- Elements designed and procured by NASA and installed by Bechtel.
  - Crew access arm and other vehicle interface umbilicals

Integrated Critical Design Review

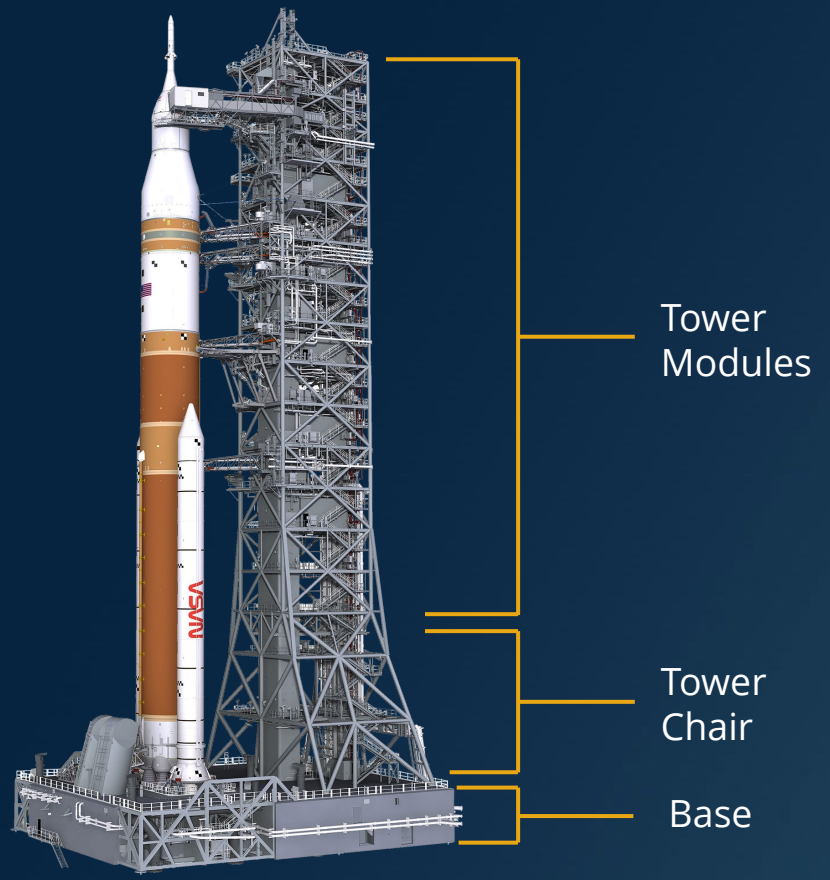
- Conducted with NASA partners to ensure agency standards are met and prepared for eventual handover.
- Overall review of each subsystem and their integration.

Business System Integration

- Earned Value Management System compliance certified by DCMA.
- Integrated Baseline Reviews conducted throughout execution.
- Collaboration to support overall Artemis Campaign needs in a multi-program strategy.

Integrated EPC

Mobile Launcher Design



Mobile Launcher 2 is the largest construction project in NASA's portfolio.

- **Sections:** Base, Tower, Modules
- **Electrical rooms:** Climate controlled and pressurized rooms that support subsystem functions pre, during, and post launch.
- **Umbilicals:** Structures that allow the launch control to communicate and supply the rocket which disconnect instantly upon launch.

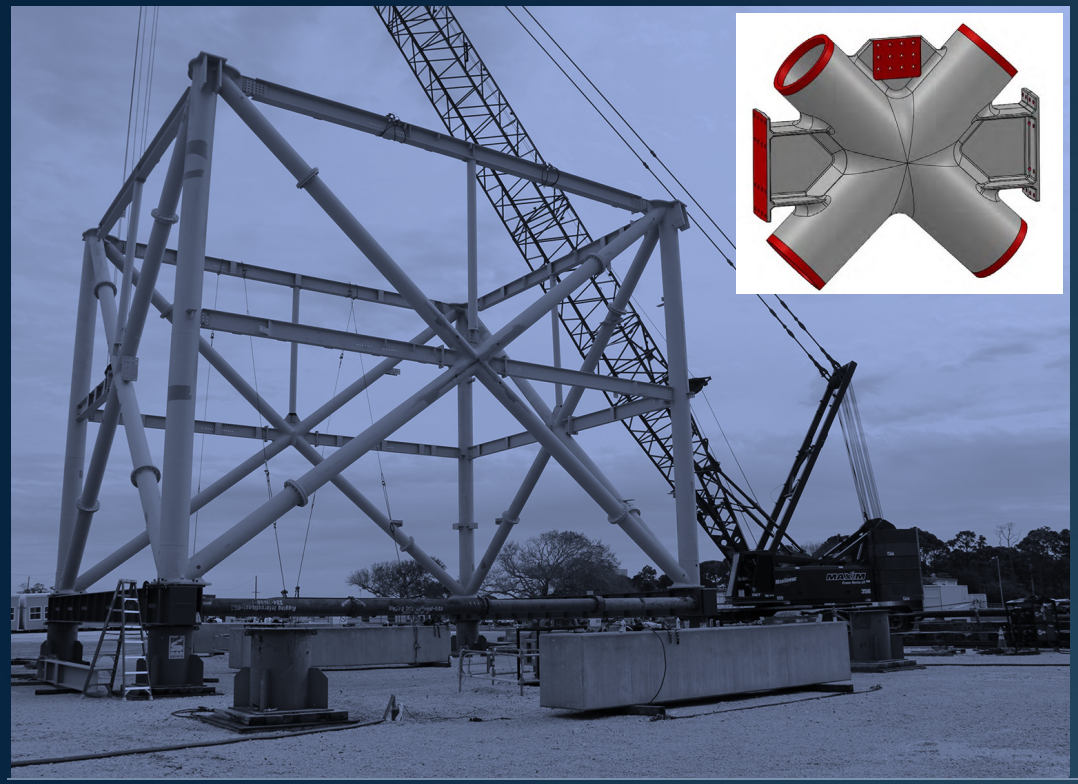
53 systems supporting 4 Major Scopes:

- Fluid & Gas
- Mechanical & Launch Accessories
- Electrical, Command, Control and Communications
- Launch Facilities

EPC Innovation

Cast Connex Nodes (Weight Reduction)

- Engineering has worked with Cast Connex to create specialized “nodes” at key crosspoints in the tower, with 104 to be installed.



Advanced Work Packaging (Data Centric Integration)

Early construction engagement to align the project team with the Construction Execution Plan.

- Outline optimal work sequencing
- Ensure constructability in design
- Track/close all work constraints prior to field execution
- Ensures the Construction Execution Plan supports the overall project schedule, startup and commissioning, and handover to customer

CIVIL CONSTRUCTION WORK PACKAGE COVER SHEET

WORK PACKAGE NO :	MOD-04-C-ML5-X-001		
CONSTRUCTION VOLUME:	MOD-04		
WBS: MOD-04		SYSTEM: ML5	
FIELD ENGINEER:	CARUBIO	SUPERINTENDENT:	
GENERAL FOREMAN:			
STEEL	3.3.C.000.M04.ST.13.1140	HOURS: 1679	
WELD	3.3.C.000.B00.ST.13.12A0	HOURS:	
WELD	3.3.C.000.B00.ST.13.12BC	HOURS:	

WORK DESCRIPTION

MOD04 PRIMARY STEEL

IWP REMARKS

(At a minimum, note preliminary steps requiring tests before starting work and before witness, or hold points, etc., in this section)

OTHER NOTES/REFERENCES:

COMMENTS:
See "Foreman's Book" for additional details such as:
o Steel Specifications
o Steel Erection Procedures
o Coatings Specifications
o General Structural Notes Drawing
o Standard Details Index Drawing

Contact the Responsible Field Engineer with any questions and or concerns.

EPC Innovation

Robust information and tools at the workplace

- **Data Vaults -** Multi-purpose data vaults the field team can access at the Parksite and Mod Yard providing access to:
  - Docking stations for laptops and tablets
  - Direct viewing access to the ML2 model and drawings
  - Key information like inspection records and work packages
- **Push To Talk (PTT) –** All General Foremen and Foremen are being provided PTTs to stay connected, as well as issuing field non-manuals tablets to support work planning and measuring productivity.

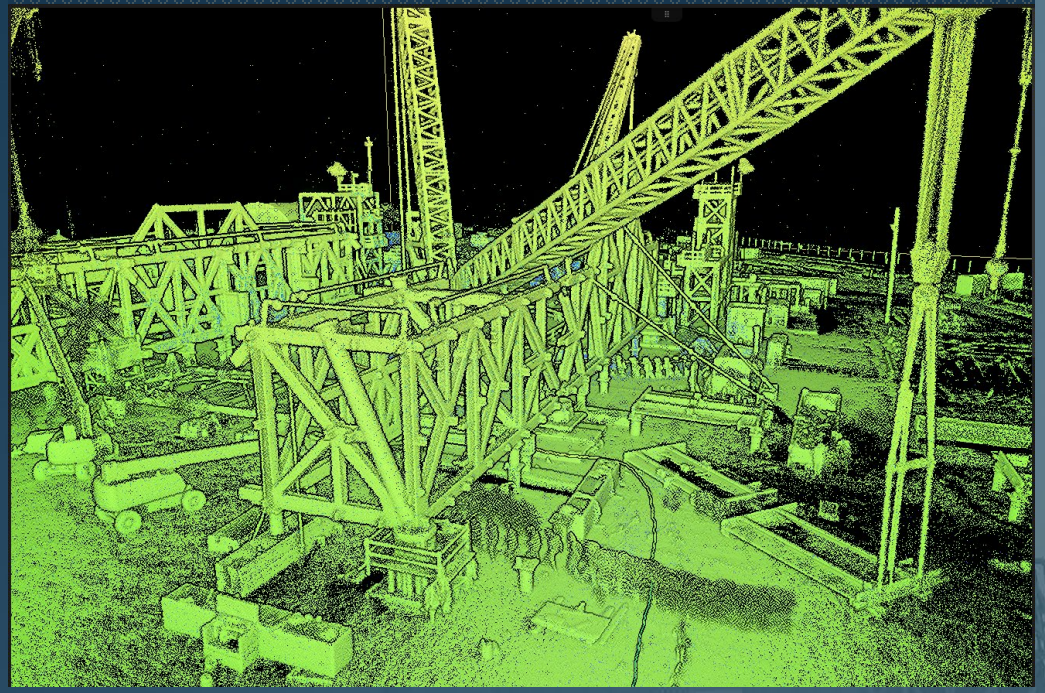
EPC Innovation

Survey

- Precision verifications to ensure tight tolerances are being met as materials are installed.

SLAM Lidar Scanning

- Uses digital equipment to take a 3-D scan of the construction site.
- Assists in tracking as-built configuration, site materials, and weight management.



Procurement Delivering to Meet Construction Need Dates

Barge Deliveries

Steel suppliers are shipping structural steel by barge to allow for:

- Reduced moves and traffic constraints
- Optimized process integration

Steel trusses arrive by barge to Kennedy Space Center

A steel truss being processed inside the blasting and coating facility.

Coatings Yard

To streamline the steel fabrication process, a coatings yard was installed at Kennedy.

- Allows for quality control on-site
- Engagement between Construction and Fabrication
- Easy access for issue resolution

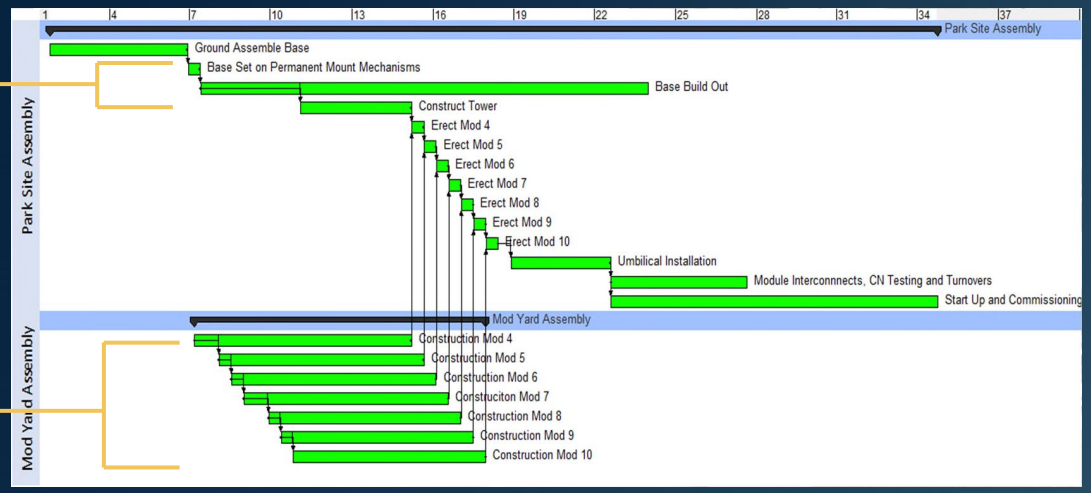
Construction Work Flow Optimization

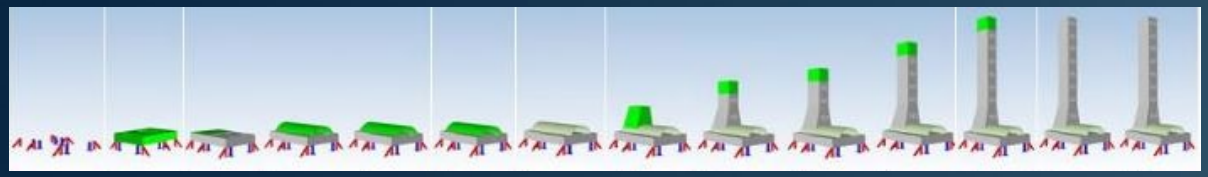
To progress construction more efficiently, the team is assembling the launcher in two areas:

- Base assembly at the Parksite near permanent mount mechanisms and Crawler way.
- Modular assembly of the tower at the Mod Yard.

Base Assembly

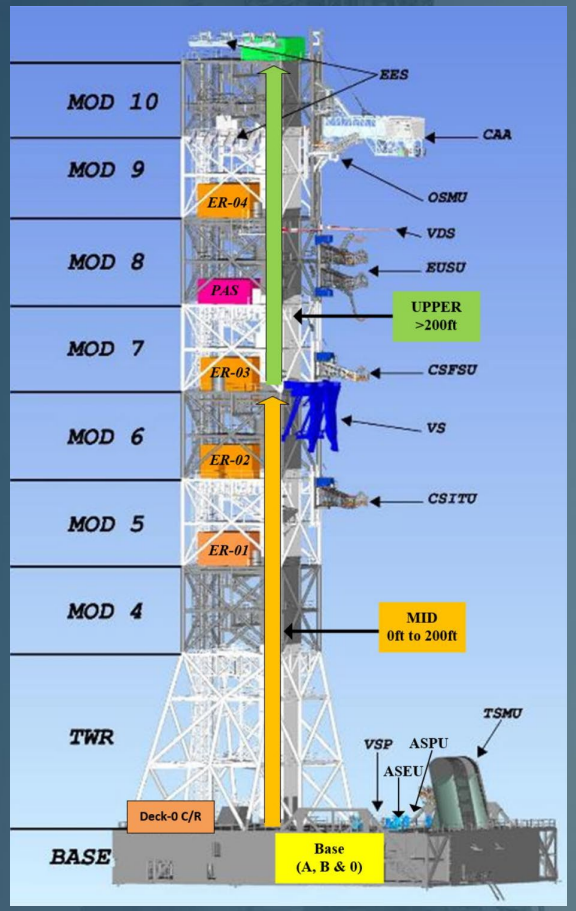
Tower Mod Assembly



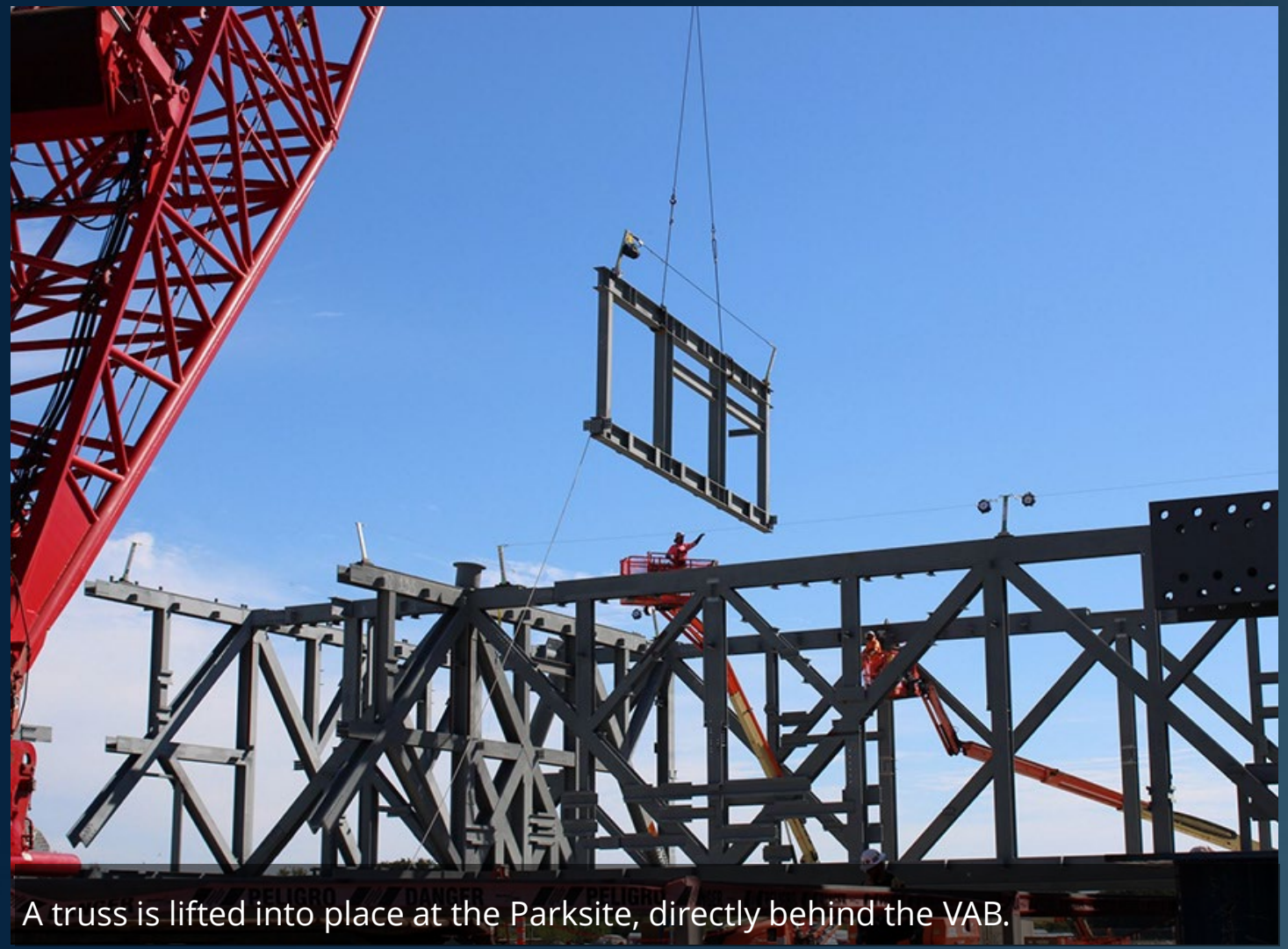


Individual tower modules assembled at Mod Yard

Base assembled at Parksite



Base Assembly



A truss is lifted into place at the Parksite, directly behind the VAB.

- The primary steel in the base is being assembled 8 feet above the ground on temporary mount mechanisms.
- Once primary steel assembly is complete, “Jack and Set” will bring the mobile launcher assembly to its permanent height of 25 feet off the ground.
- Assembling primary steel closer to the ground decreases risk associated with elevated work.

Tower Modules

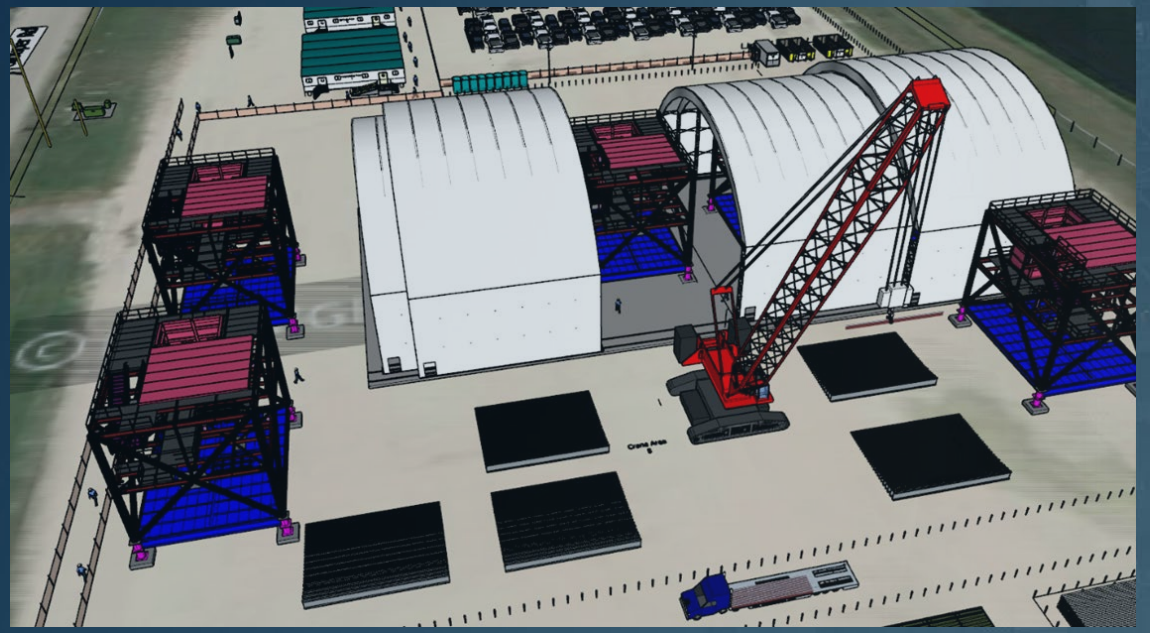
The 7 Tower Modules are being built at a second site:

- Leverage available acreage at Kennedy
  - Prevents work at extreme elevations
- Application of lessons learned in real time
  - As the modules are completed, issues can be identified and resolved in the current module and applied to the next.

The primary steel for the first of 7 tower modules is assembled at the Mod Yard near NASA Headquarters at Kennedy Space Center.

Adapting to the Florida Space Coast

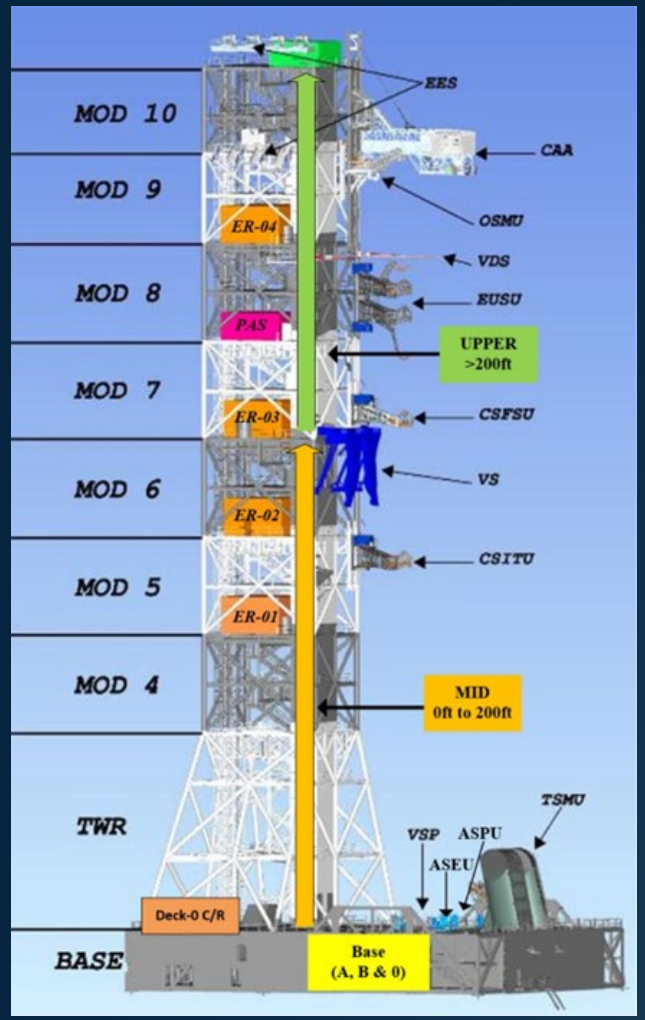
- Kennedy Space Center has one of the highest rates of lightening strikes in the United States.
- To ensure module assembly is not weather dealyed, the Mod Yard has been outfitted with a **lightening protection system** that can be moved over the modules allowing safe work during a summer storm.




Jun 28 2025
TSMU: Mech Install Umbilical (Tail Service Masts Umbilical)
VDS: Mech Install Umbilical (Vehicle Damper)

Turnover to NASA

Startup and Commissioning



Integrated into every step of the design and construction process

The Commissioning and Startup team has been providing feedback and recommendations at every stage to prepare for turnover of the launcher.

Specialized testing for the launcher includes:

- **Cold Shock Testing** – ensures proper installation of equipment exposed to cryogenics.
- **Instrumentation Verifications** – Specialized testing for unique subsystems such as: fluids and gases, electrical systems, and command, control and communications.
- **Vehicle Integration** – Ensuring the launcher is prepared for interface with the vehicle and existing NASA systems.

Mobile Launcher 2

One Team, One Mission
Moon to Mars

Questions