Early-Career Reflections on College and Engineering

Matthew Denny

Propulsion Engineer

The Boeing Company

Outline

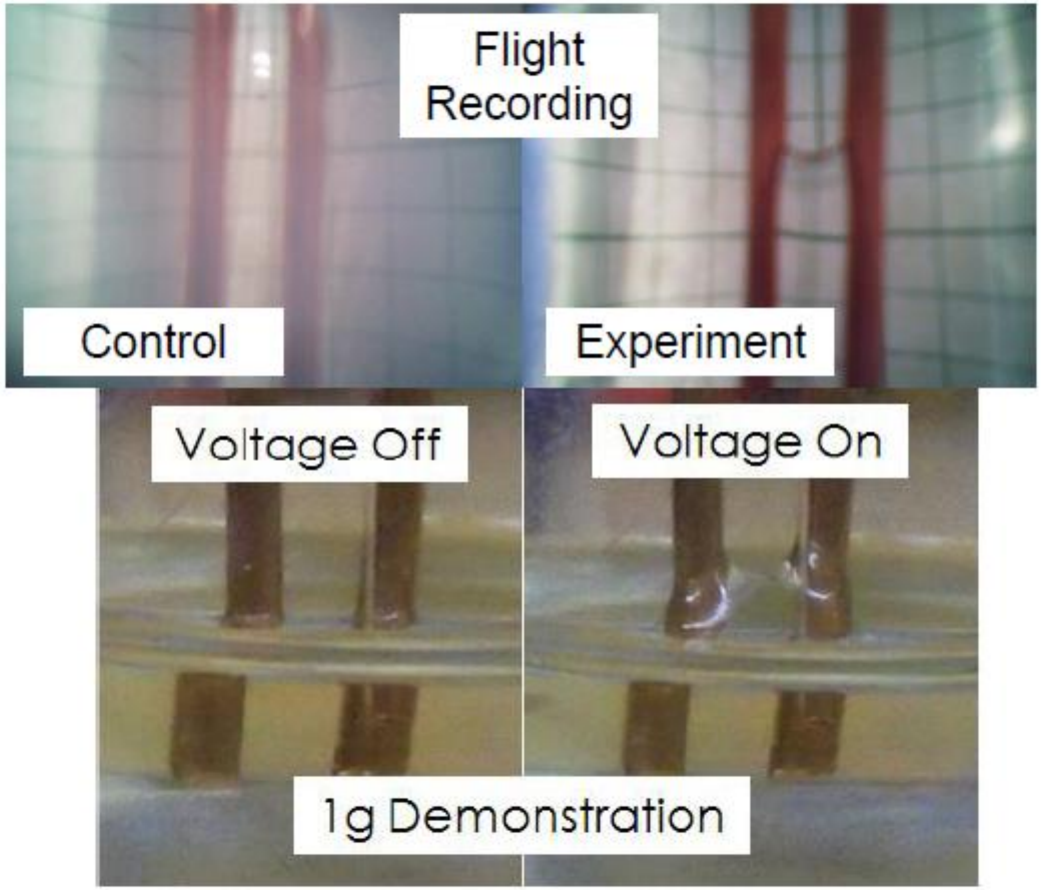
- Background at UAH
- Space Launch System (SLS) at Boeing
  - Overview of development programs in general
  - Propulsion
  - Flight Termination System (FTS)
  - Separation Systems

University Student Launch Initiative 2012-2013

Motor: J-355
Apogee: 5360 ft
Max Velocity: 700 ft/s
Separation Altitude: 3000 ft
Max Acceleration: 8.8 g's

Charger Rocket Works

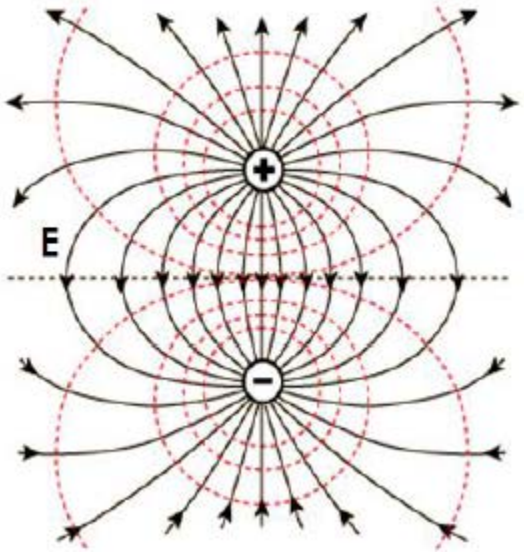
USLI Payload Experiment: Dielectrophoresis
(Thanks Dr. Blackmon!)



Theory

- Dielectrophoresis: a force induced on an initially non-polar fluid particle in a non-uniform electric field
- Acts in the direction of the gradient of the electric field
- Electric field of parallel electrodes draws fluid to central location

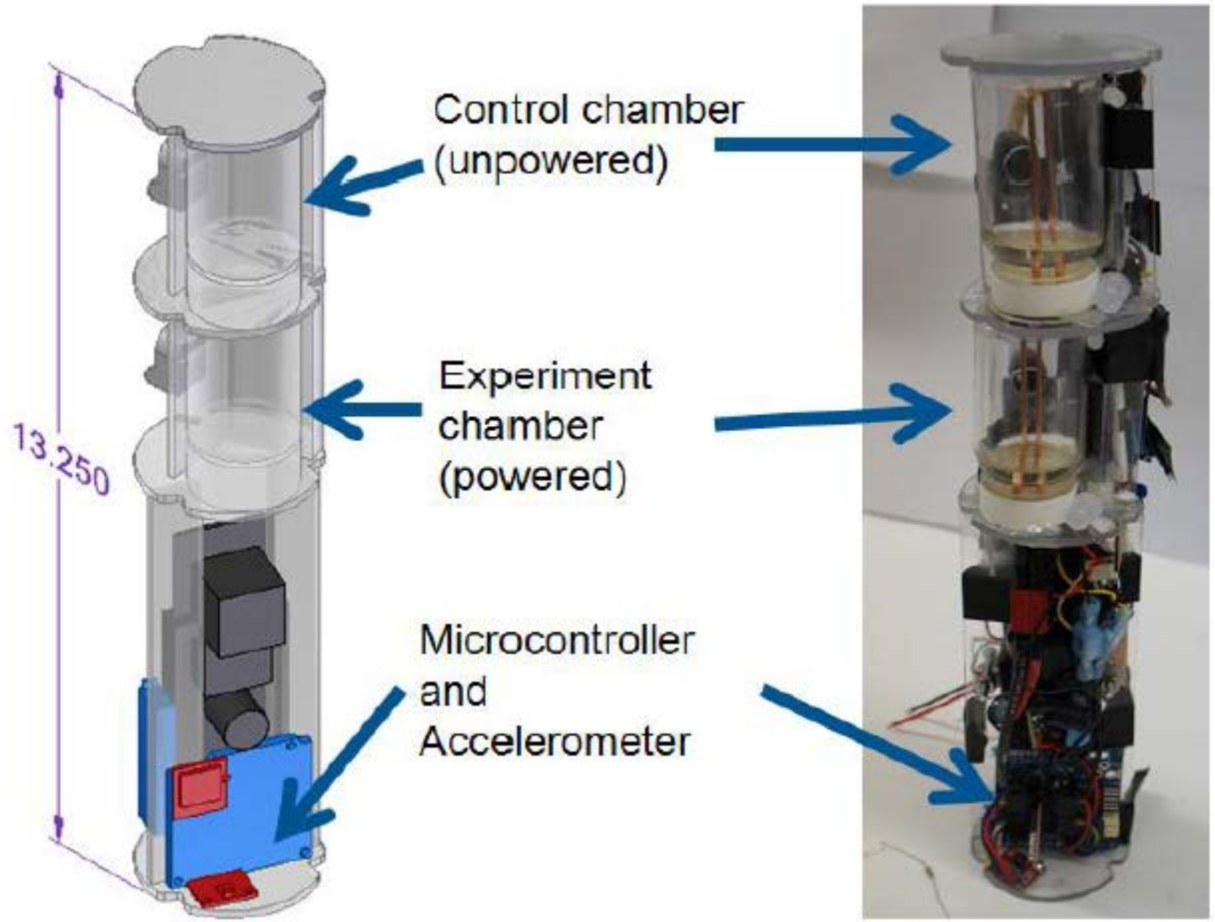
$$\vec{F}_v = \frac{\varepsilon_0 (K-1)(K-2)}{6} \nabla E^2$$



USLI Payload Experiment Testing

<u>Testing at acceleration test facility</u>

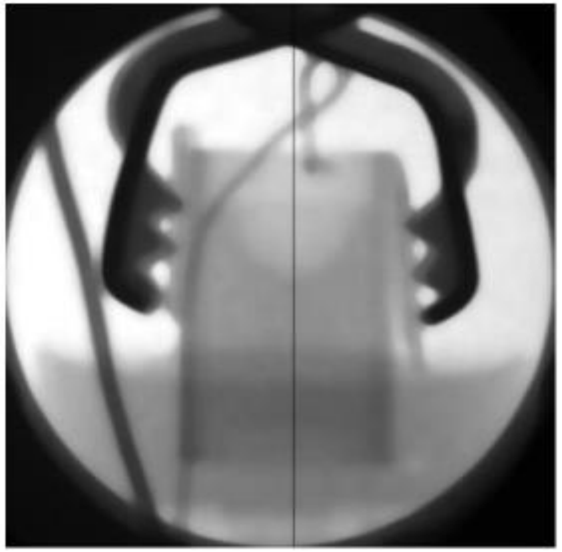
Codename: Space Shot

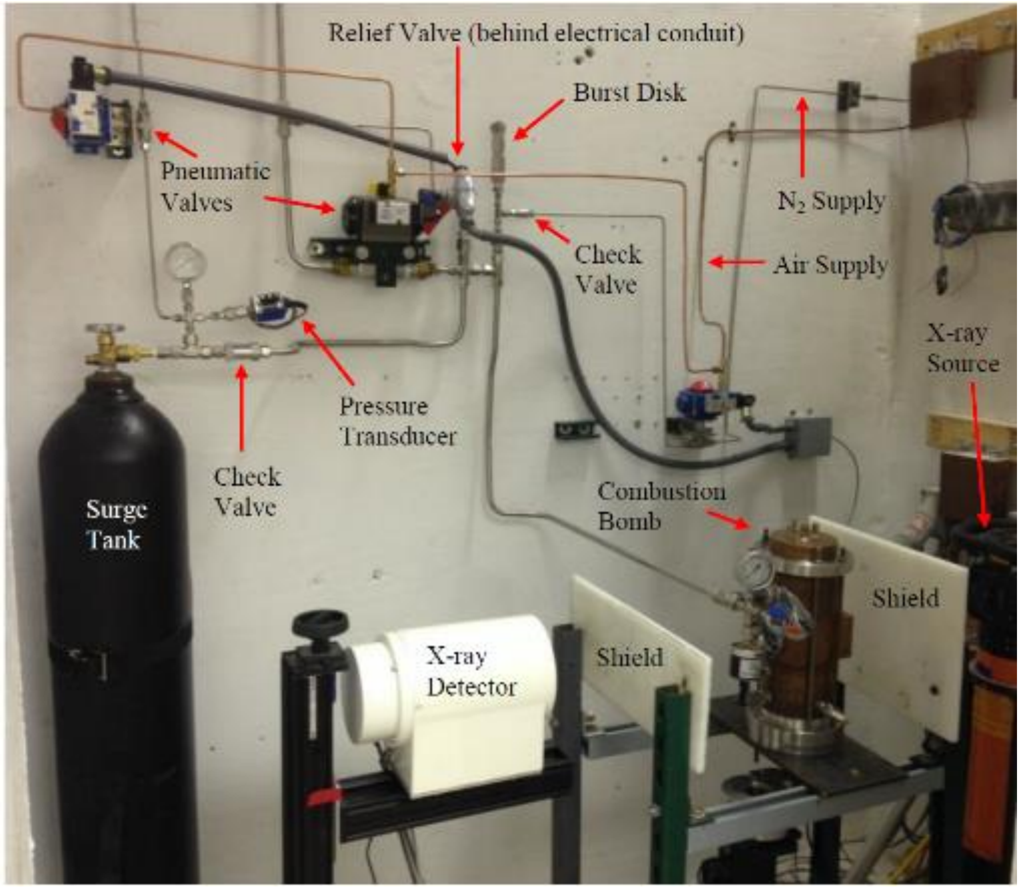


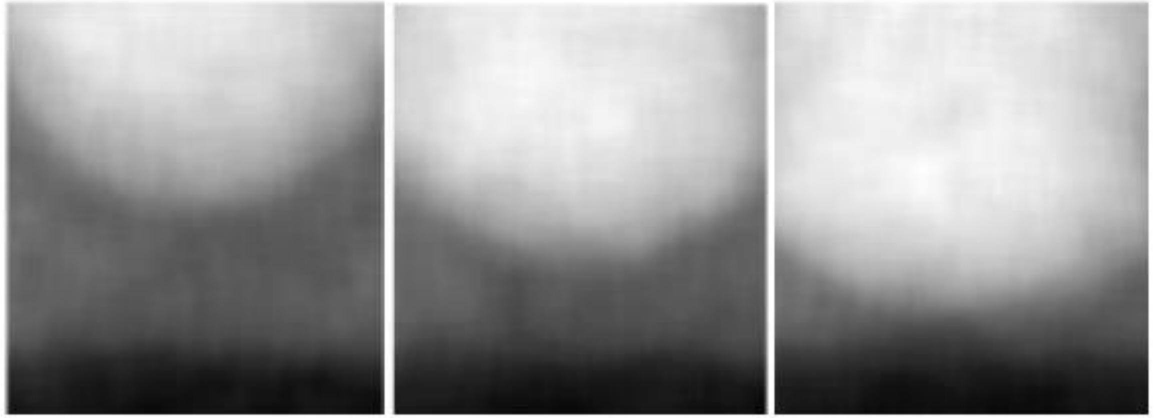
UAH Propulsion Research Center

High Pressure Lab

Solid Propellant Sample

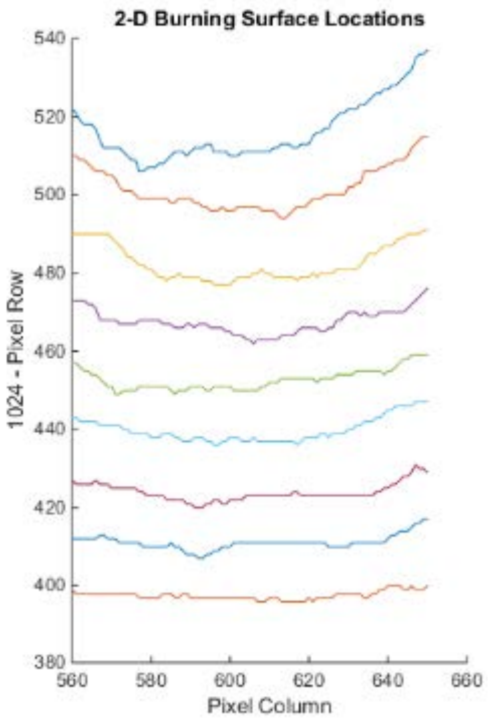


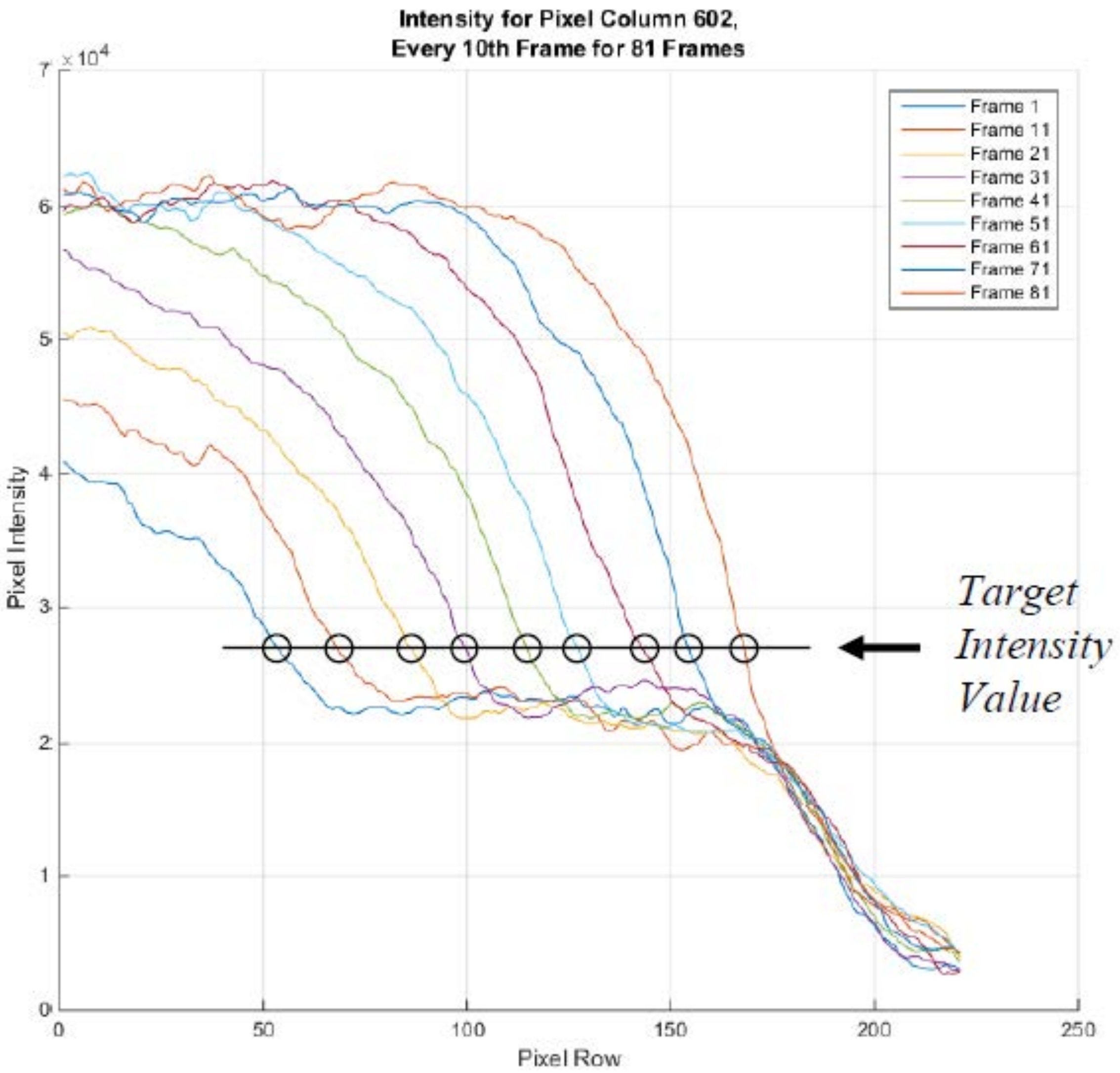


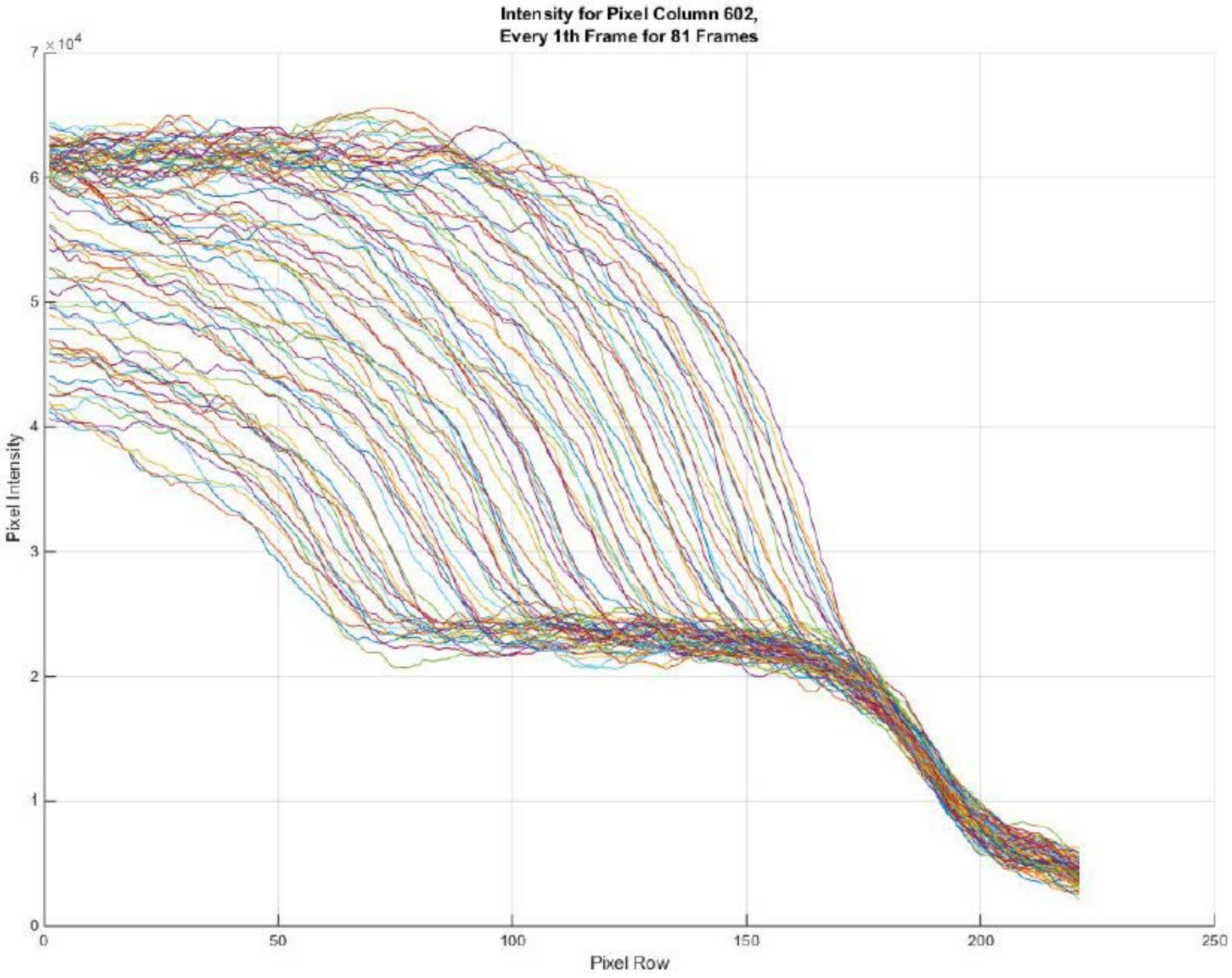


Burning surface regression in X-ray video frames

“Measurement of Solid Rocket Propellant Burning Rate Using X-ray Imaging”






Intensity for Pixel Column 602,
Every 1th Frame for 81 Frames
Pixel Intensity
Pixel Row
×10^4
0
1
2
3
4
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7
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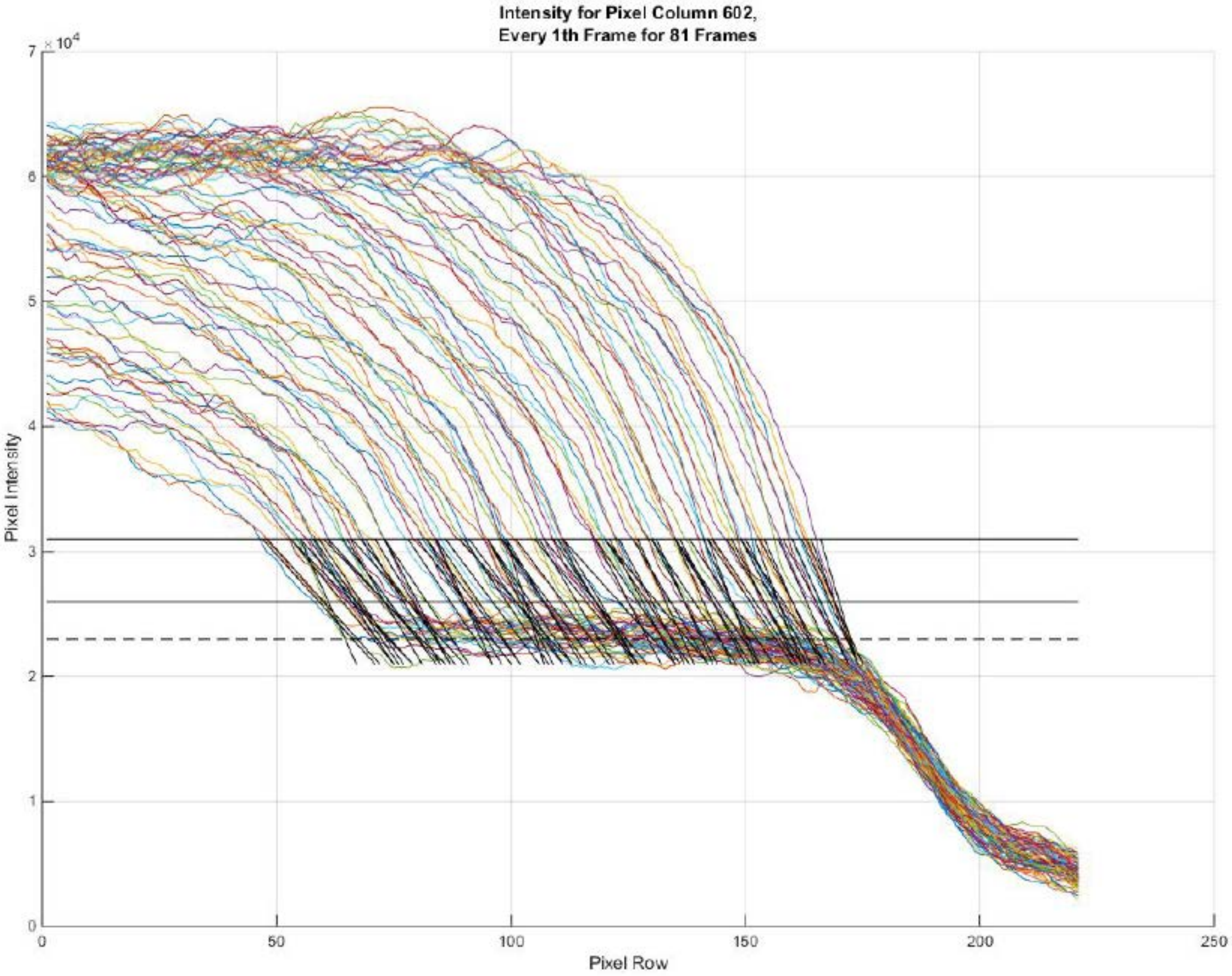
50
100
150
200
250


Intensity for Pixel Column 602,
Every 1th Frame for 81 Frames
× 10^4
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Pixel Intensity
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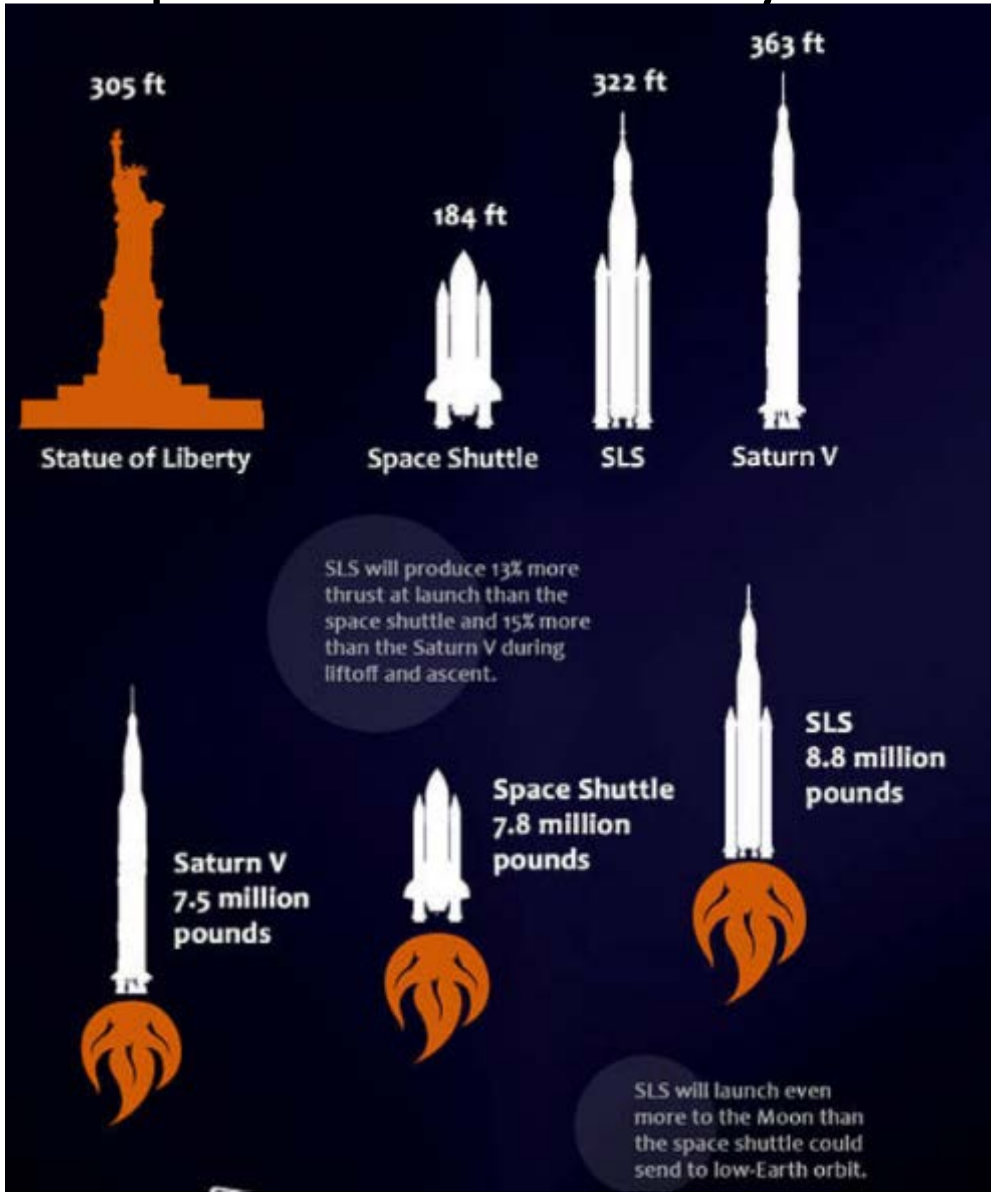
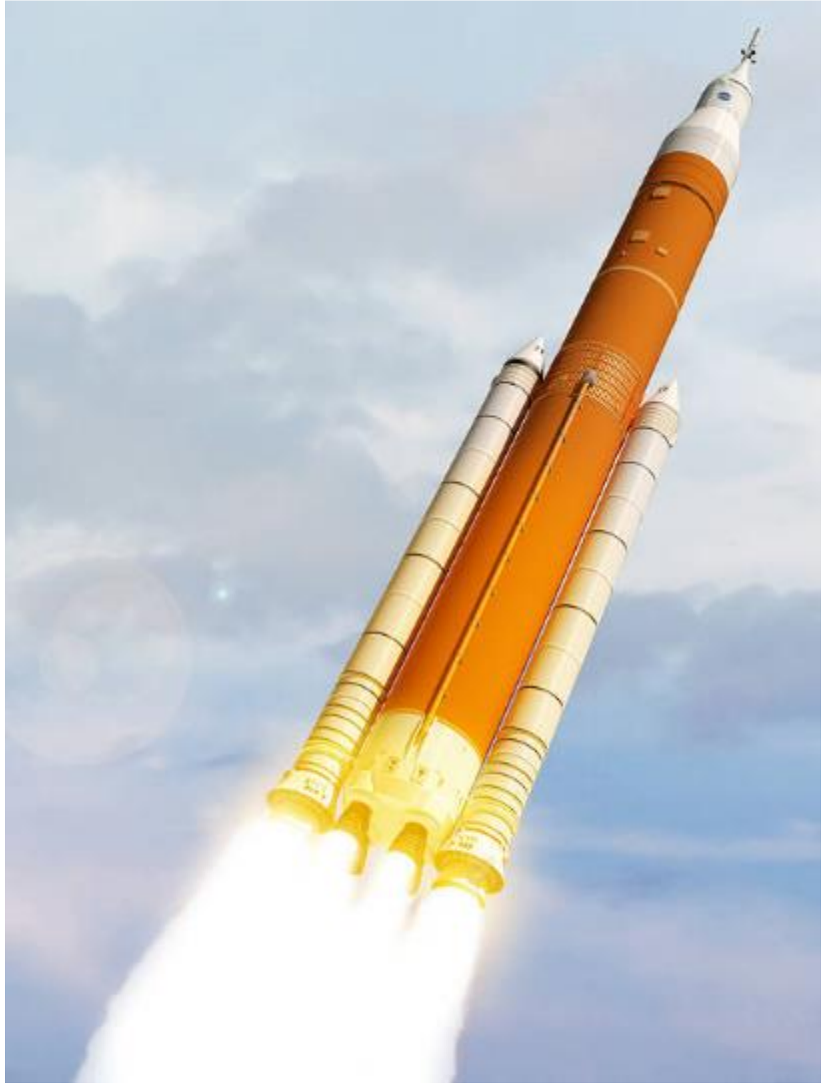
150
200
250
Pixel Row

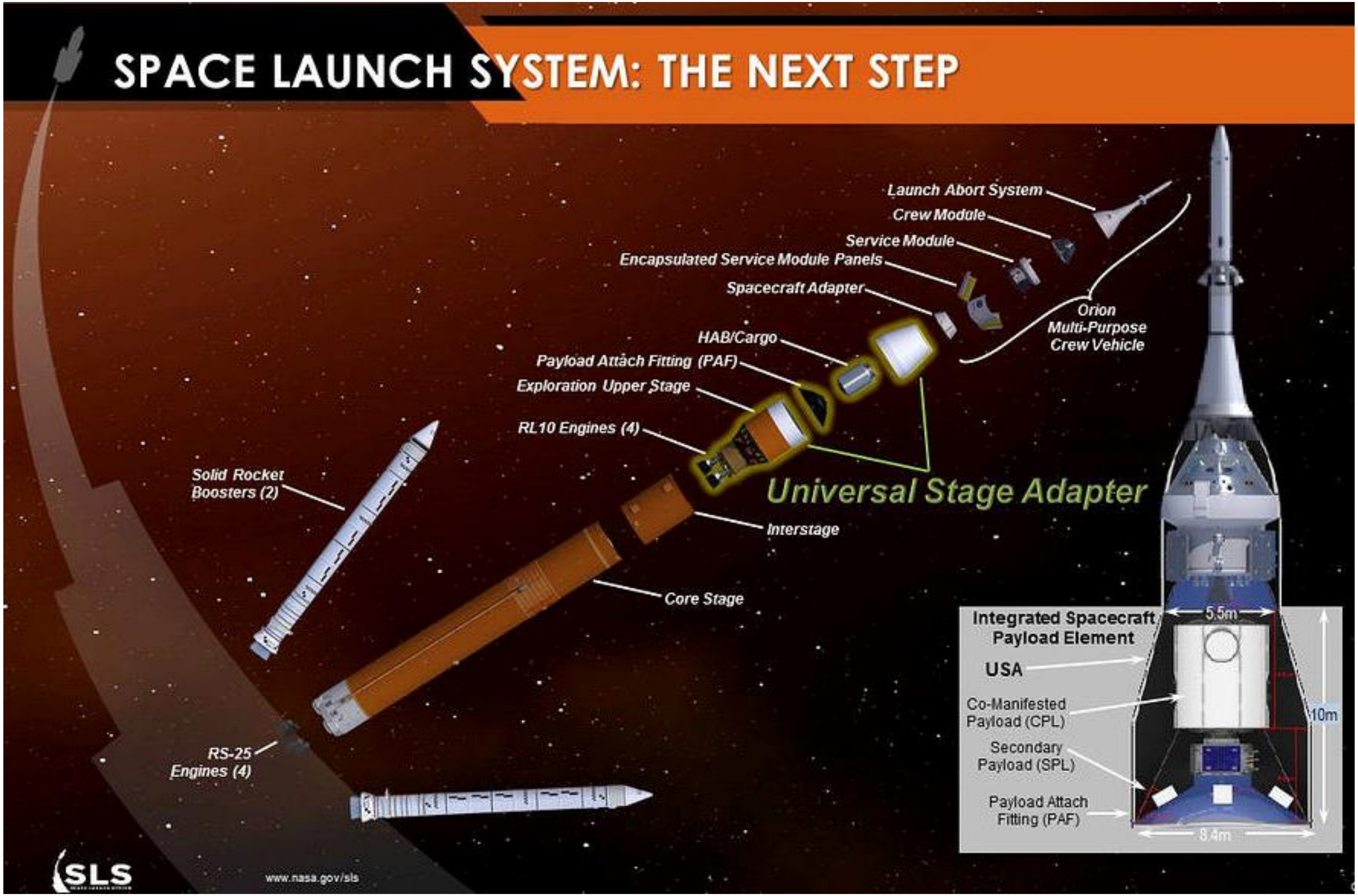
Space Launch System (SLS)



https://www.nasa.gov/sls/multimedia/gallery/sls-infographic3.html



https://www.nasa.gov/exploration/systems/sls/multimedia/gallery/SLS_Concepts.html



https://www.nasa.gov/exploration/systems/sls/multimedia/gallery/SLS_Concepts.html

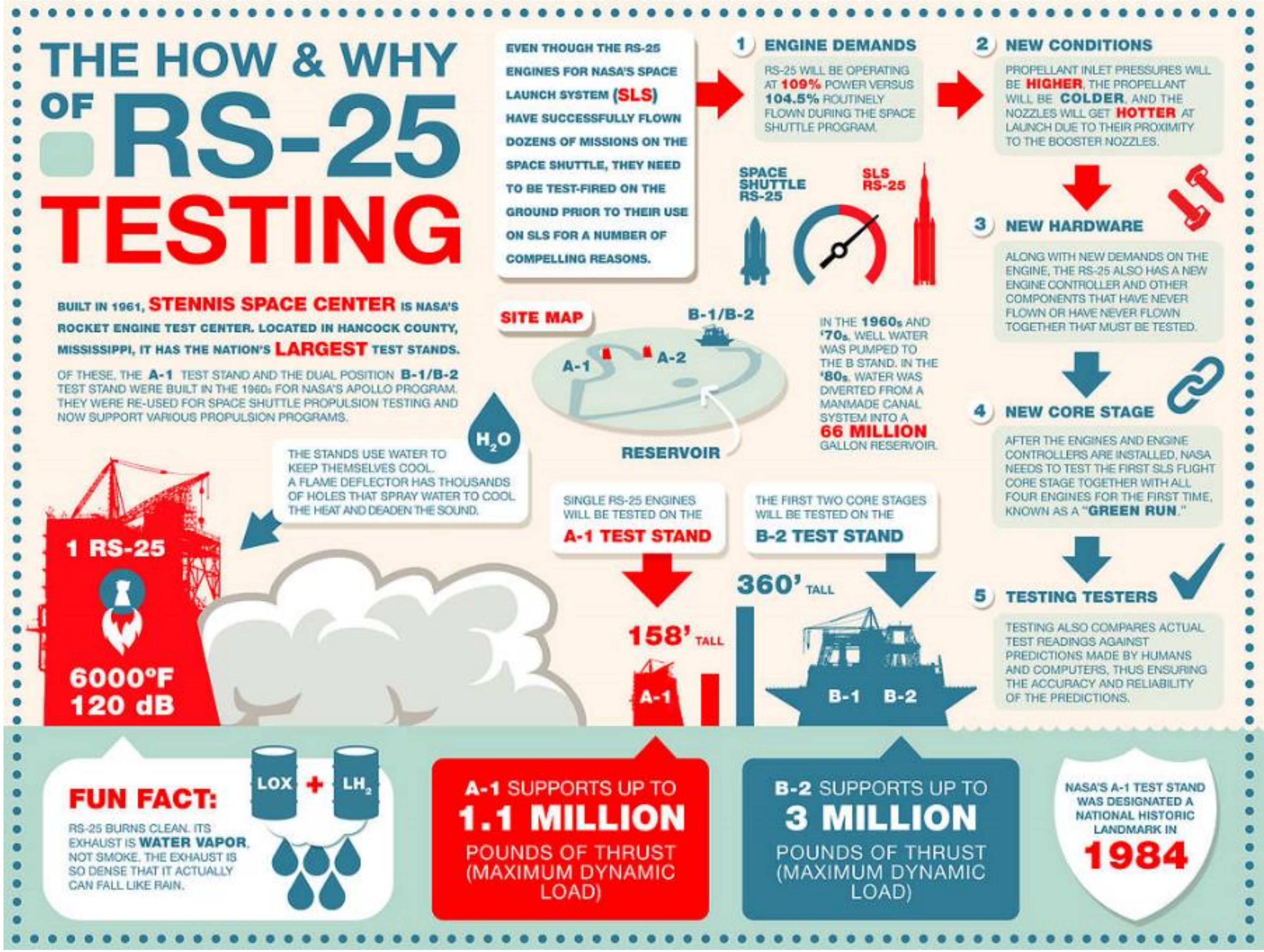
https://www.nasa.gov/sites/default/files/atoms/files/sls_lift_capabilities_and_configurations_508_08202018_0.pdf

RS-25 Engine – Aerojet Rocketdyne

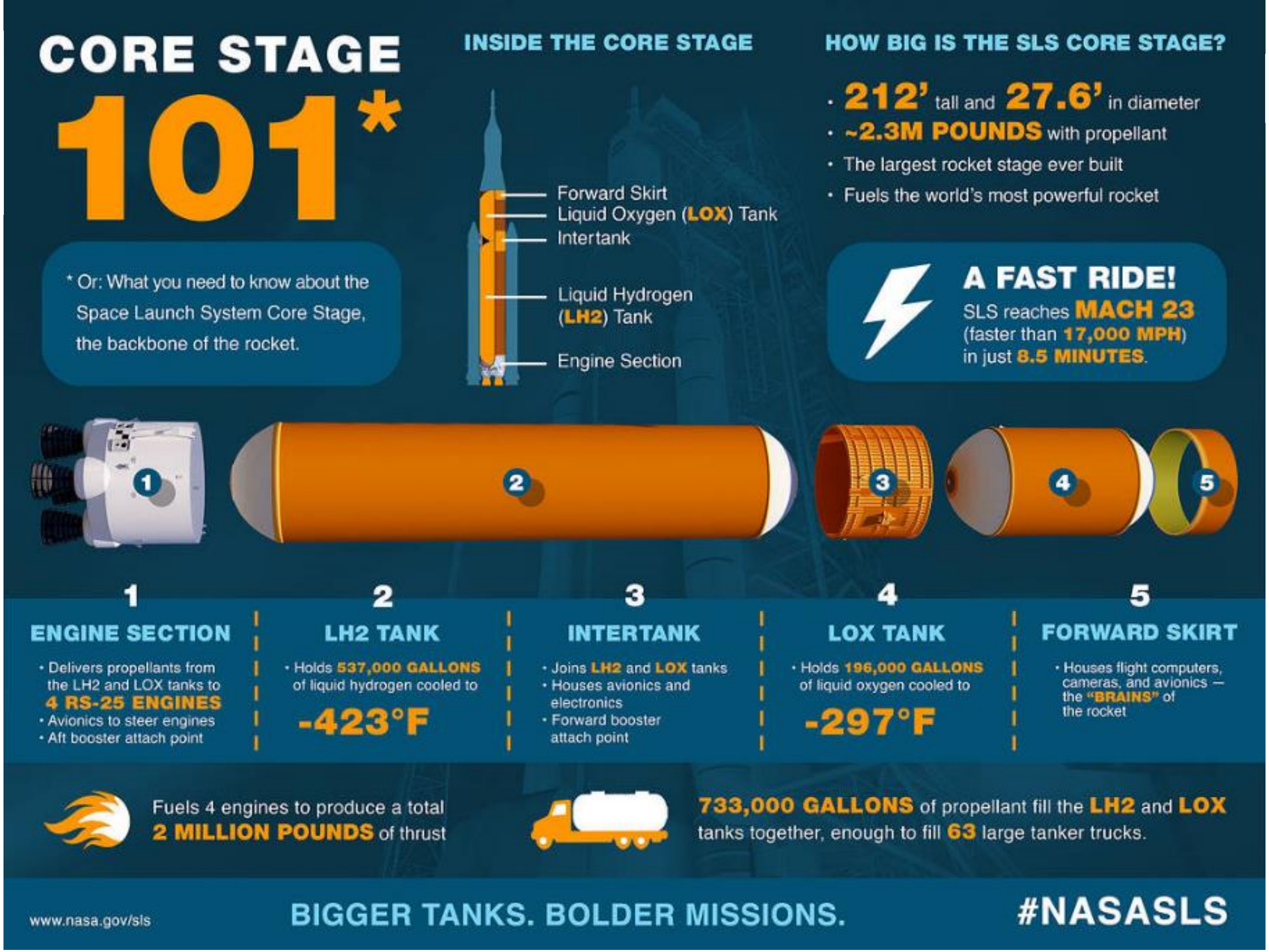
https://www.nasa.gov/exploration/systems/sls/multimedia/hardware.html

Stennis Space Center (SSC)

https://www.nasa.gov/exploration/systems/sls/multimedia/hardware.html



https://www.nasa.gov/exploration/systems/sls/multimedia/infographics.html



https://www.nasa.gov/exploration/systems/sls/multimedia/infographics.html

Michoud Assembly Facility (MAF)

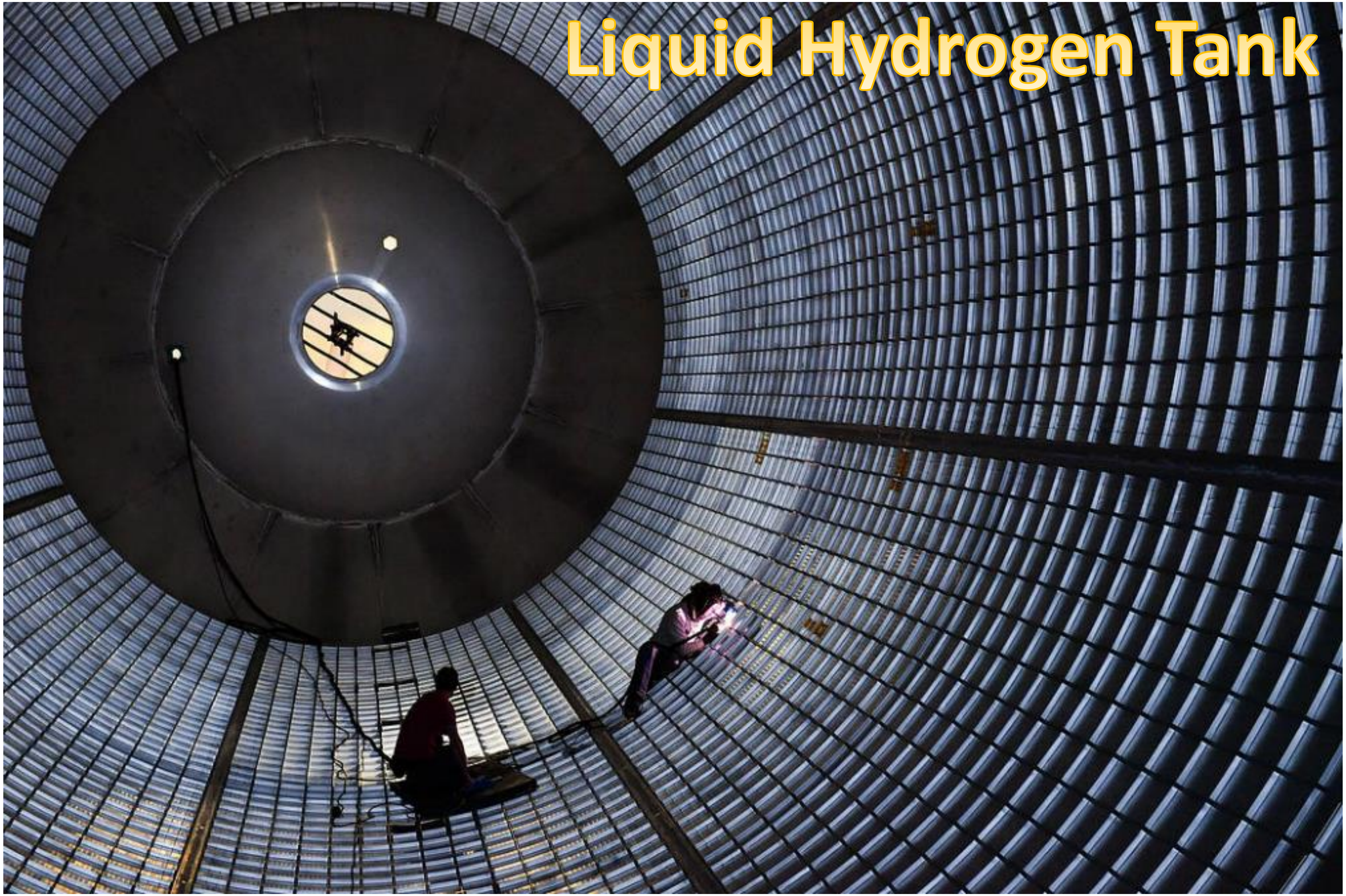
https://en.wikipedia.org/wiki/Michoud_Assembly_Facility

Engine Section at Michoud Assembly Facility (MAF)

https://www.nasa.gov/exploration/systems/sls/multimedia/hardware.html

Qualification Liquid Hydrogen Tank at MAF

Qualification Liquid Hydrogen Tank at MSFC



https://www.nasa.gov/exploration/systems/sls/multimedia/hardware.html

Liquid Oxygen Tank at MAF

https://www.nasa.gov/exploration/systems/sls/multimedia/hardware.html

Solid Rocket Booster (SRB) – ATK / Northrop Grumman

Solid Rocket Booster Details

Length: 177 feet

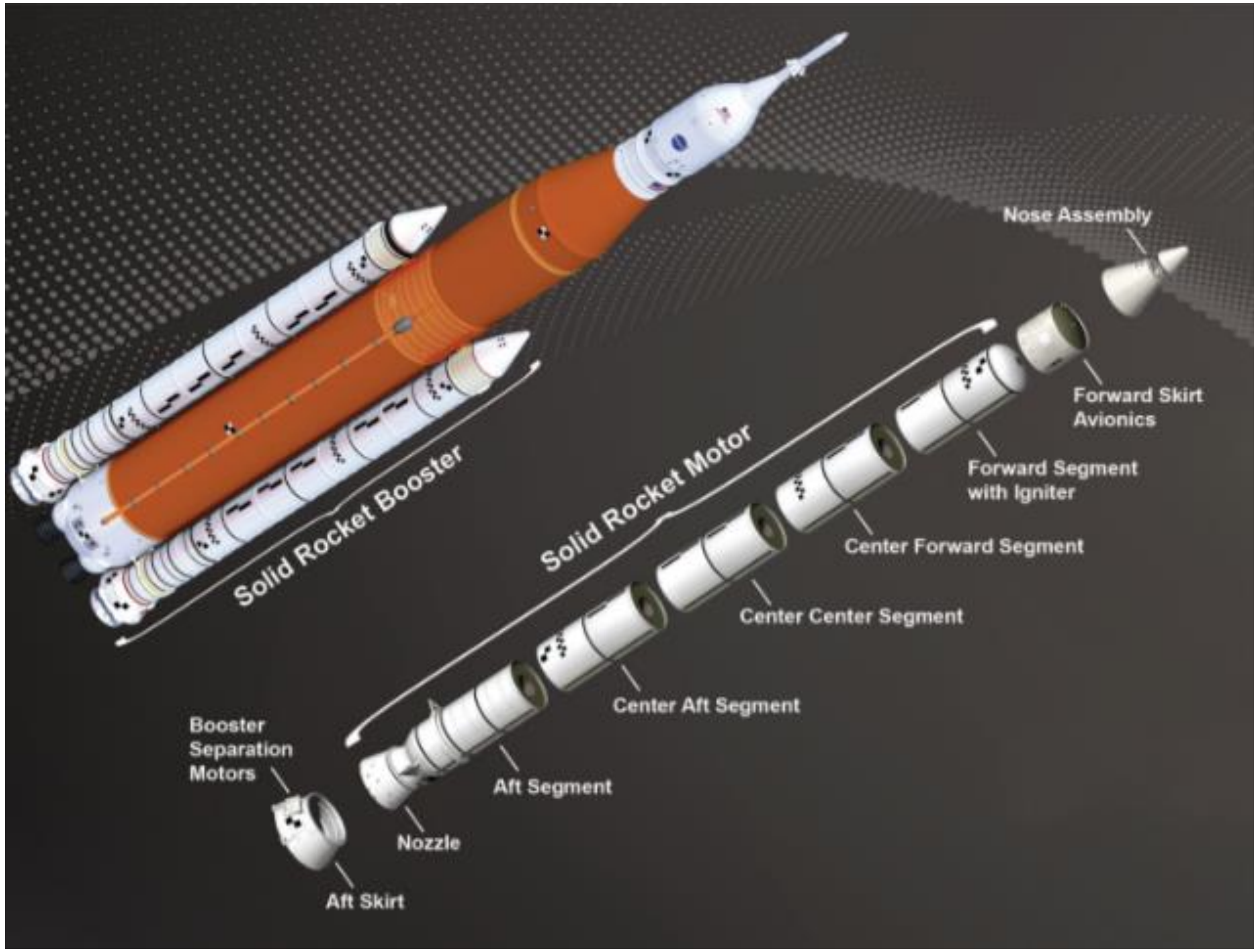
Diameter: 12 feet

Weight: 1.6 million pounds each

Propellant: polybutadiene acrylonitrile (PBAN)

Thrust: 3.6 million pounds each

Operational time: 126 seconds



https://www.nasa.gov/sites/default/files/atoms/files/sls_solid_rocket_booster_fact_sheet_final_508_june2018.pdf

Upper Stage for First Launches (SLS Block 1)

Interim Cryogenic Propulsion Stage (ICPS) – Boeing/ULA

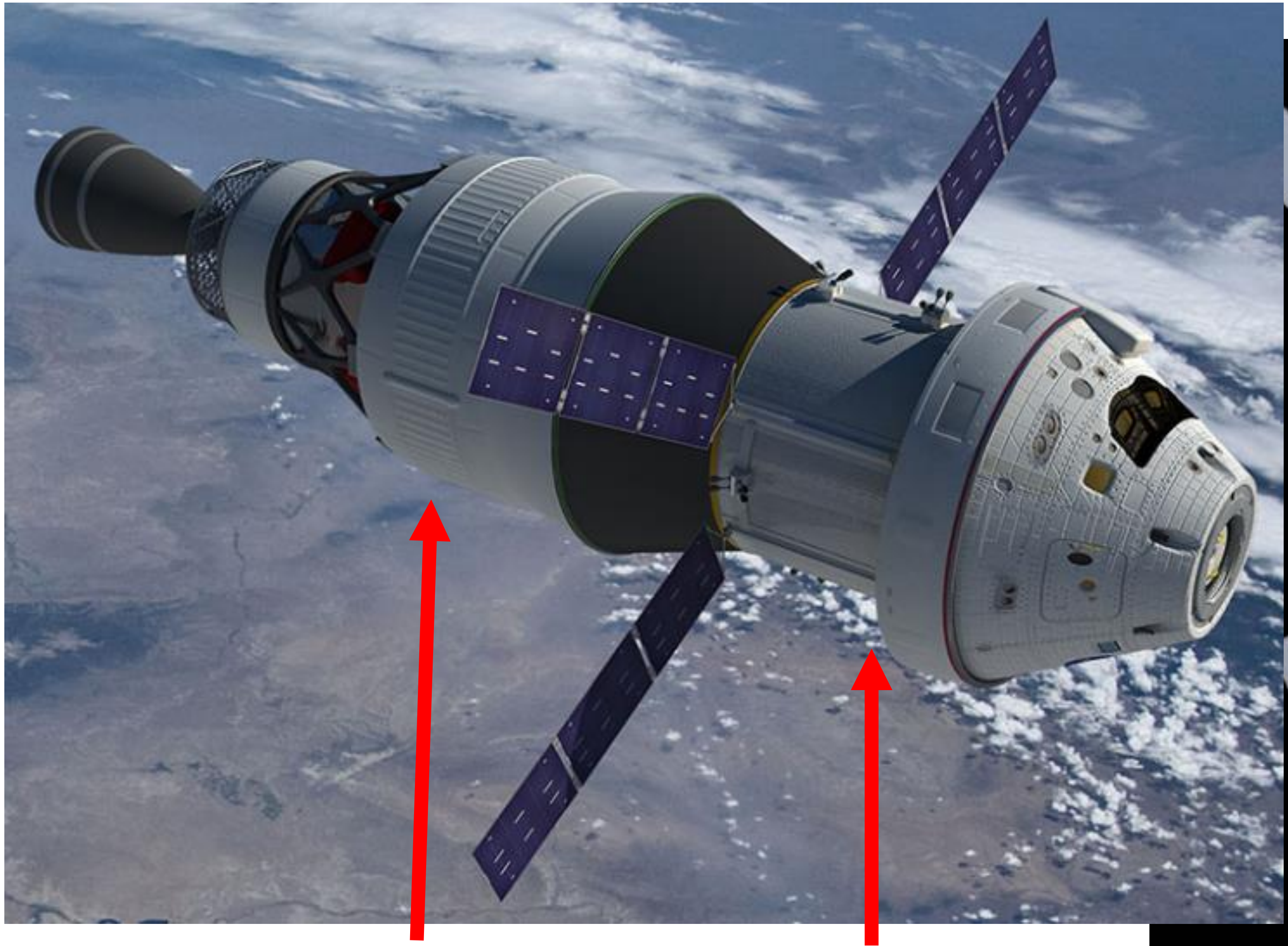
BOEING

ULA
United Launch Alliance

RL-10 Engine made by Aerojet Rocketdyne (formerly Pratt & Whitney Rocketdyne)

https://www.nasaspaceflight.com/2017/07/sls-upper-stage-residency-former-home-iss-modules/

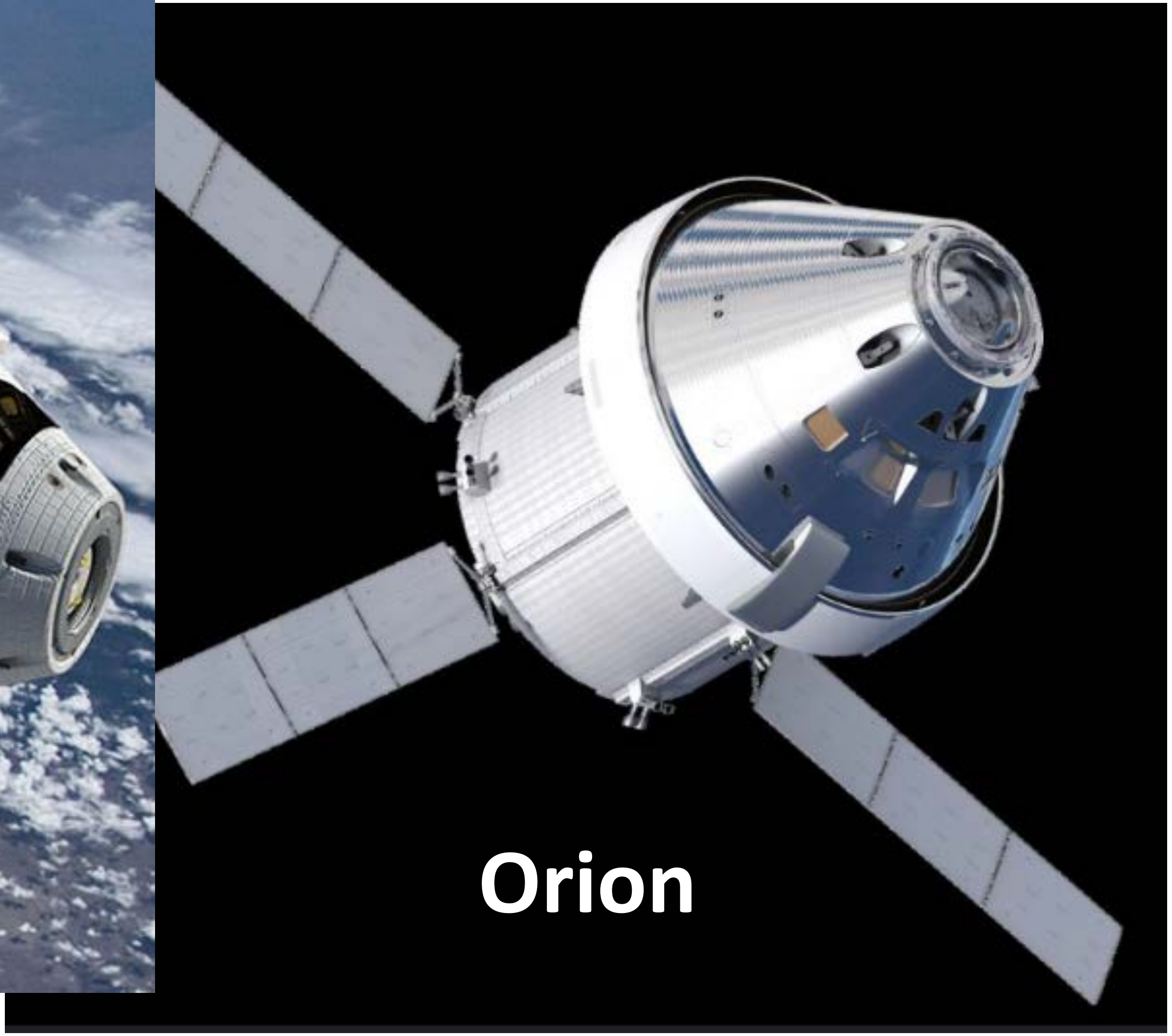
Orion – Lockheed Martin



ICPS

Orion

https://www.nasa.gov/sls/interim_cryogenic_propulsion_stage_141030.html



https://www.nasa.gov/exploration/systems/orion/index.html

Final Integration and Launch from Kennedy Space Center

https://www.google.com/search?biw=1536&bih=754&tbm=isch&sa=1&ei=x_-mXI-7DLDI_QbcgKmgDQ&q=sls+at+kennedy+space+center&oq=sls+at+kennedy+space+center&gs_l=img.3...4105.4795..5141...0.0..0.92.541.7......1....1..gws-wiz-img.SzIop5vcGmg#imgrc=LKQlb8QL0HscuM:

Flight Termination System (FTS)

Ground-controlled FTS

Ref 1
RF Antenna

Ref 2
Receiver/Decoder

Ref 5
Safe & Arm Device containing an Initiator

Ref 6
Flexible Confined Detonating Cord Assembly (FCDCA)

Ref 4
Time Delay

Ref 6
Flexible Confined Detonating Cord Assembly (FCDCA)

Ref 7
Destruct Charge

Autonomous FTS

Ref 3
Sensors

Ref 2
Logic Controller

Ref 5
Safe & Arm Device containing an Initiator

Ref 6
Flexible Confined Detonating Cord Assembly (FCDCA)

Ref 7
Destruct Charge

References:

1. https://www.google.com/search?biw=1536&bih=754&tbm=isch&sa=1&ei=W_OmXMbDC6iwjwTx3Bk&q=rf+antenna&oq=rf+antenna&gs_l=img.3..35i39j0j0i67l2j0l2j0i67j0l3.3790.3985..4247...0.0..0.75.148.2......1....1..gws-wiz-img.C88or3I47tk
2. https://www.google.com/search?biw=1536&bih=754&tbm=isch&sa=1&ei=8POmXLQfi_uPBLzujMgN&q=avionics+box&oq=avionics+box&gs_l=img.3...28030.29472..29572...0.0..0.0.0.......1....1..gws-wiz-img.u0_s7hVDcII
3. https://www.google.com/search?ei=rvWmXIvEJuzIjwSShbDACg&q=accelerometers&oq=accelerometers&gs_l=psy-ab.3..0j0i20i263j0l8.3147.4625..4757...0.0..0.97.1137.14....2..0....1..gws-wiz.......0i71j35i39j0i67j0i228j0i131i67j0i131.TZQnBxBh1h8
4. https://www.eba-d.com/products/time-delay-assembly/
5. https://psemc.com/products/electromechanical-safe-and-arm-device-esad/
6. https://www.eba-d.com/products/flexible-confined-detonating-cord-assembly-fcdca/
7. https://psemc.com/products/destruct-charge/

Destruct Charges

LINEAR SHAPED CHARGE
CONFIGURATIONS RANGE
(IN LENGTH)
6 INCHES TO 10 FEET

DESTRUCT CHARGE
CONFIGURATIONS RANGE
(IN DIAMETER)
1 INCHES TO 12+ INCHES

https://psemc.com/products/destruct-charge/

Linear Shaped Charge (LSC)

- Can be used for Flight Termination (destruct)
- Can be used for separation of stages, fairings, vent ports, etc.

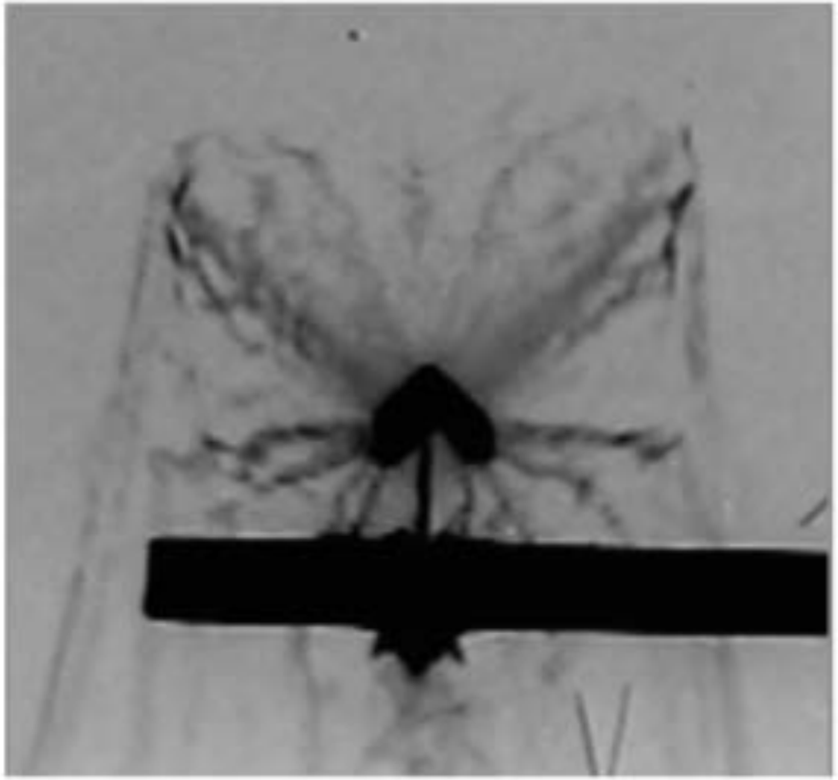


Figure 16 – Flash X-Ray of detonating LSC. High velocity fragments can be created by the detonation event. (Source: Reference 6)

https://www.eba-d.com/assets/Uploads/AIAA-2003-4436-Separation-Joint-Tech.pdf

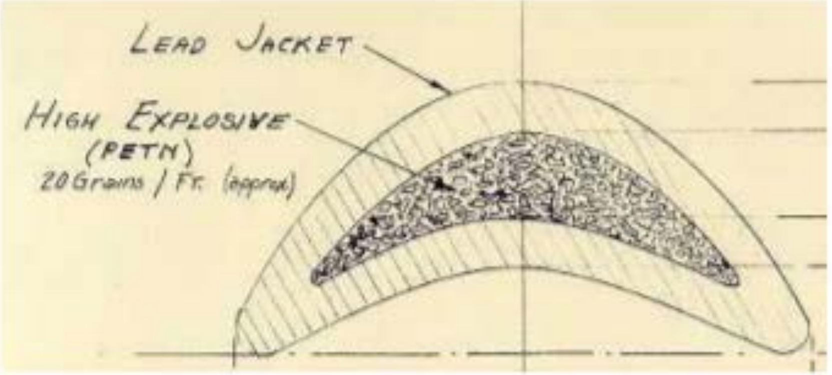


Figure 10. Early LSC cross section, circa 1957 (Source: Reference 11)

Figure 12. Some examples of current production Linear Shaped Charges (Source: EBA&D)

Frangible Joint with Expanding Tube

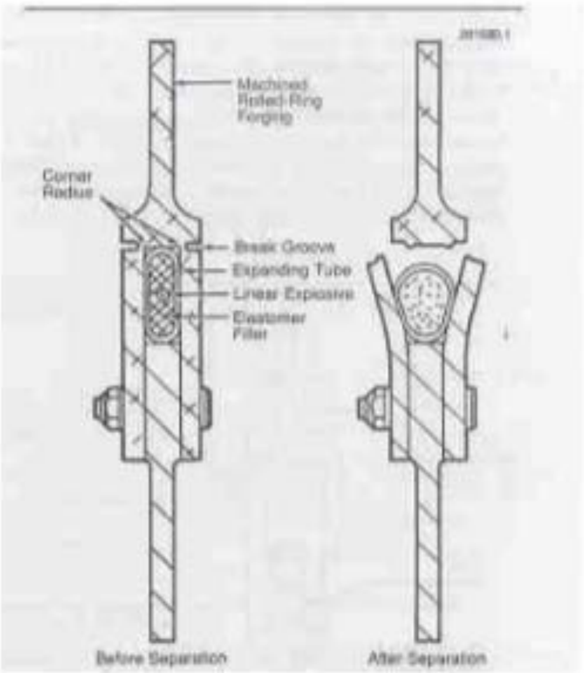


Figure 5. "Sure-Sep" Frangible Joint Configuration (Source: Reference 14)

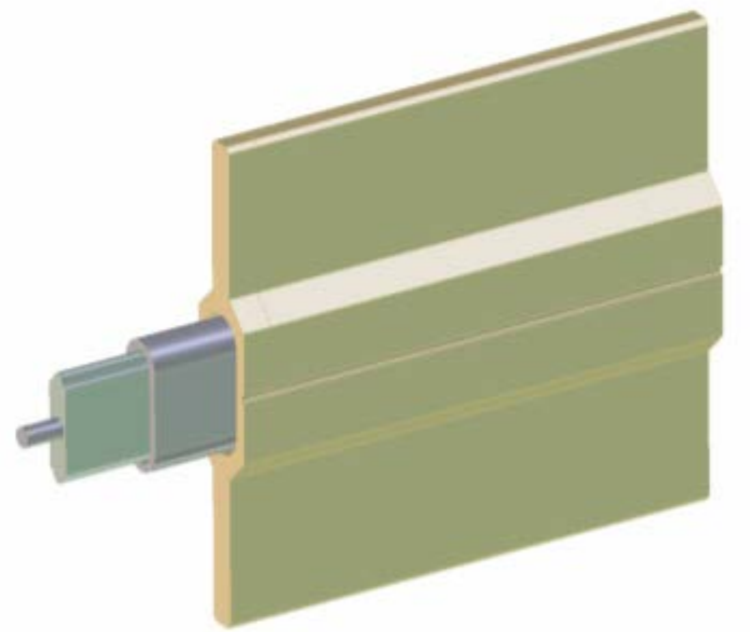


Figure 6. Solid model of hollow form extrusion frangible joint (Source: EBA&D)

Figure 7. Confined Detonating Cord Separation Joint Assembly (Source: EBA&D)

https://www.eba-d.com/assets/Uploads/AIAA-2003-4436-Separation-Joint-Tech.pdf

Separation System Comparison

Linear Shaped Charge	Expanding Tube
More debris	Less debris
More source shock	Less source shock
More simple	Less simple

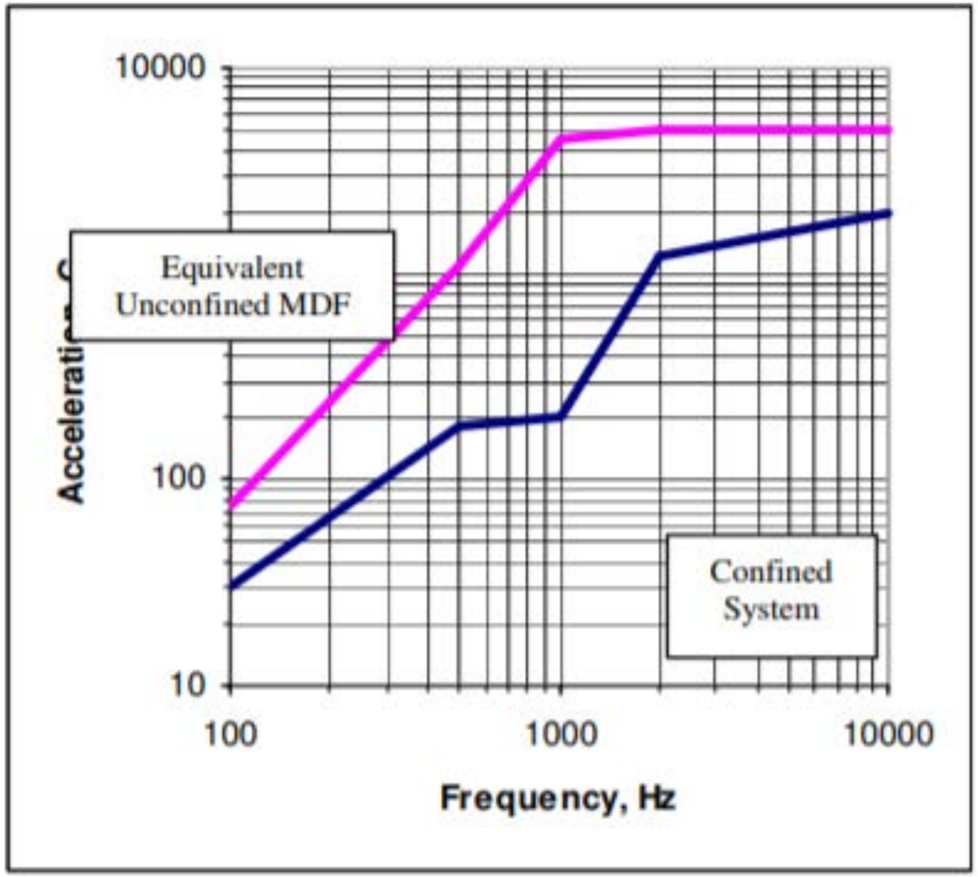


Figure 17. Comparative Data, Application of an Unconfined MDF system vs. a Confined Separation System (Source: EBA&D)

https://www.eba-d.com/assets/Uploads/AIAA-2003-4436-Separation-Joint-Tech.pdf

Overview of Component Development

- Understand the subsystem that uses the components
- Write component specification, Statement of Work (SOW), Test plans if needed
- Send Request for Proposal (RFP) package: 60 days for suppliers' responses
- Evaluate proposals using predetermined evaluation criteria: 30 days
- Issue contract award to best supplier
- Design Reviews and Testing (iterative as design matures and hardware is built)
- Delivery to Boeing
- Support subsystem testing
- Support integration onto the vehicle
- Support vehicle testing
- Support the mission

Component Specification

Types:

- Envelope Drawing (ED)
- Source Control Drawing (SCD)
- Build-to-print Drawing with notes and parts list

Requirements with Verifications:

- Functionality
- Environments: temperature, loads, pressure, vibration, shock, humidity, salt fog, electrostatic discharge, etc.
- Reliability
- Safety
- Dimensional Envelope (often includes a preliminary drawing)

Governing Specifications for SLS Ordnance

DoD Requirements and Standards

DoDD 3200.11	Major Range and Test Facility Base (MRTFB)
RCC Standard 313-01	Test Standards for Flight Termination Receivers/Decoders
RCC Standard 321-16	Common Risk Criteria Standards for National Test Ranges
RCC Standard 323-99	Range Safety Criteria for Unmanned Air Vehicles
EWR 127-1	Range User Handbook
AFSPCMAN 91-710V1	Range Safety User Requirements Manual Volume 1 - Air Force Space Command Range Safety Policies and Procedures
AFSPCMAN 91-710V2	Range Safety User Requirements Manual Volume 2 - Flight Safety Requirements
AFSPCMAN 91-710V3	Range Safety User Requirements Manual Volume 3 - Launch Vehicles, Payloads, and Ground Support Systems Requirements
AFSPCMAN 91-710V4	Range Safety User Requirements Manual Volume 4 - Airborne Flight Safety System Design, Test, and Documentation Requirements
AFSPCMAN 91-710V5	Range Safety User Requirements Manual Volume 5 - Facilities and Structures
AFSPCMAN 91-710V6	Range Safety User Requirements Manual Volume 6 - Ground and Launch Personnel, Equipment, Systems, and Material Operations Safety Requirements
AFSPCMAN 91-710V7	Range Safety User Requirements Manual Volume 7 - Glossary of References, Abbreviations, and Acronyms, and Terms.

https://kscsma.ksc.nasa.gov/RangeSafety/reqDocs/DoDlinks

MEASUREMENT SYSTEM INCH-POUND

National Aeronautics and Space Administration

MSFC-SPEC-3635
REVISION C
EFFECTIVE DATE: JUNE 25, 2018

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

EV30

MSFC TECHNICAL STANDARDS

PYROTECHNIC SYSTEM SPECIFICATION

Approved for Public Release; Distribution is Unlimited

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

https://standards.nasa.gov/standard/msfc/msfc-spec-3635

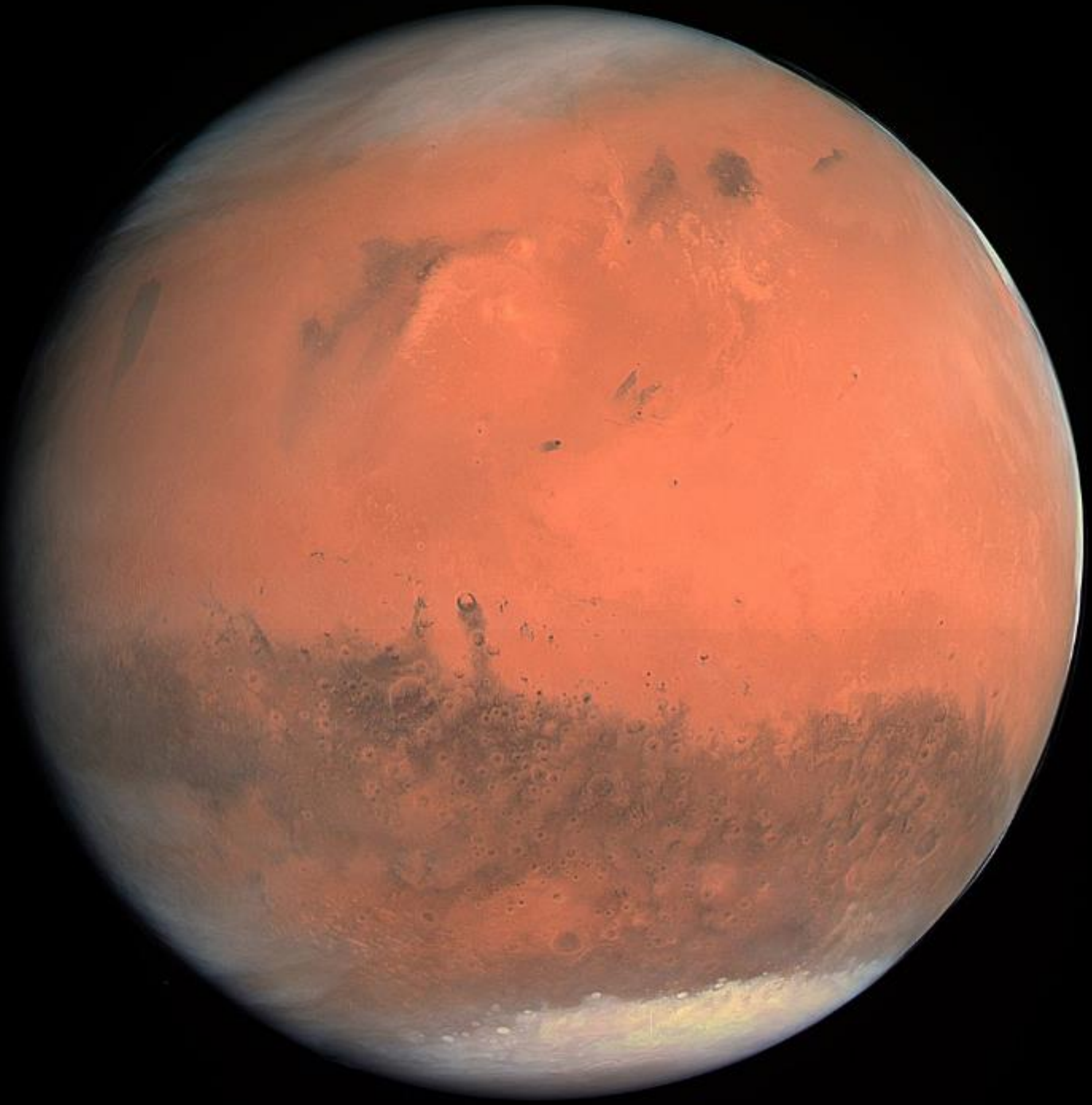
Component Testing

- Development Testing
- Qualification Testing
- Acceptance Testing

Component Reviews

- Pre-Contract Requirements Review
- System Requirements Verification Review
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Test Readiness Review (TRR)
- Acceptance Review (AR) or Hardware Acceptance Review (HAR)

Questions?



https://en.wikipedia.org/wiki/Mars