Solid Rocket Motor Design and Analysis

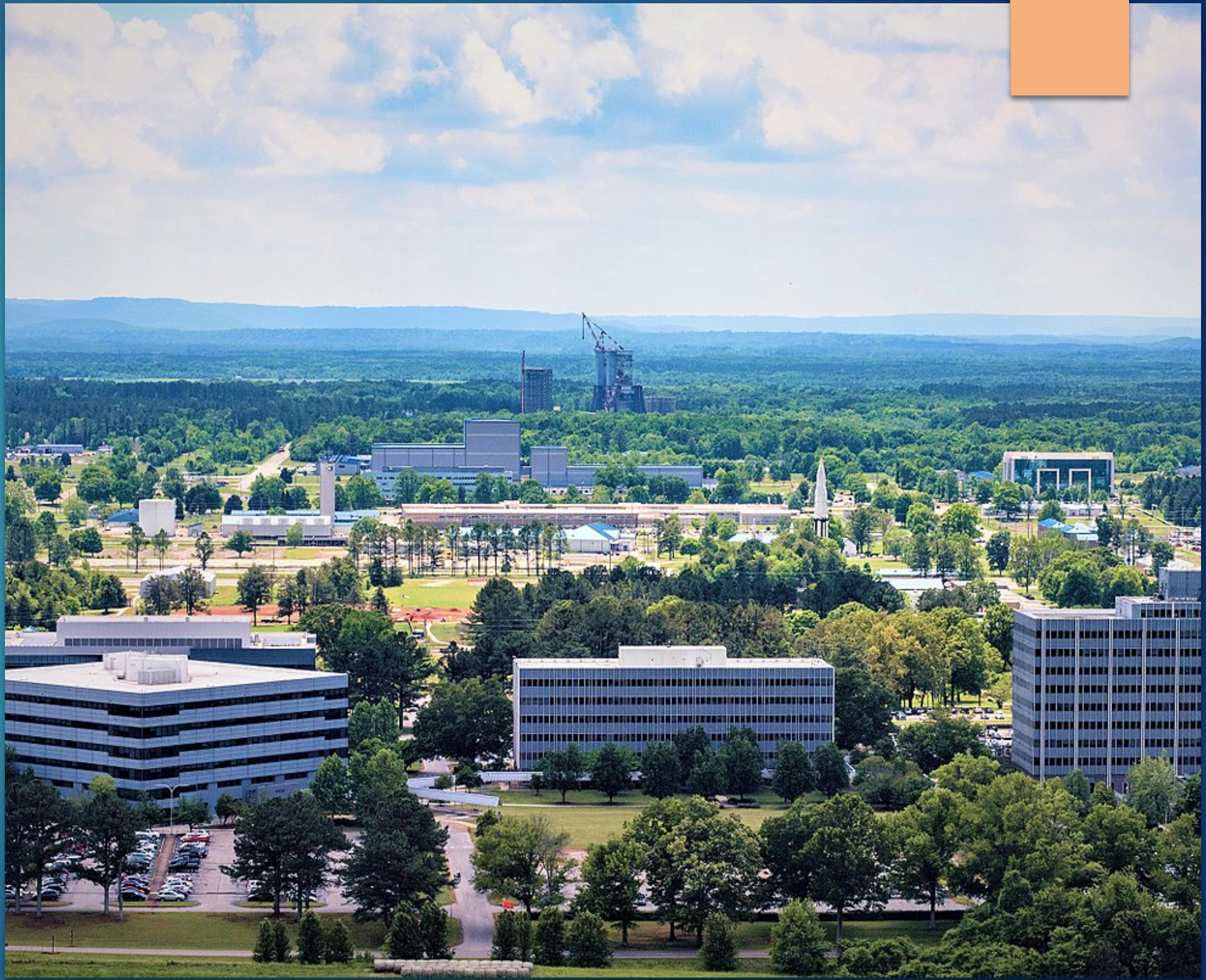
DEVON BURSON

MENTORS: BRET ABLES
BEN GAUVAIN

ORG: ER51

Marshall Space Flight Center

- Huntsville, Alabama
- 6,000 Civil Servants & Contractors
- Located on Redstone Arsenal
- NASA's Propulsion Center
- Currently Building the Space Launch System (SLS)



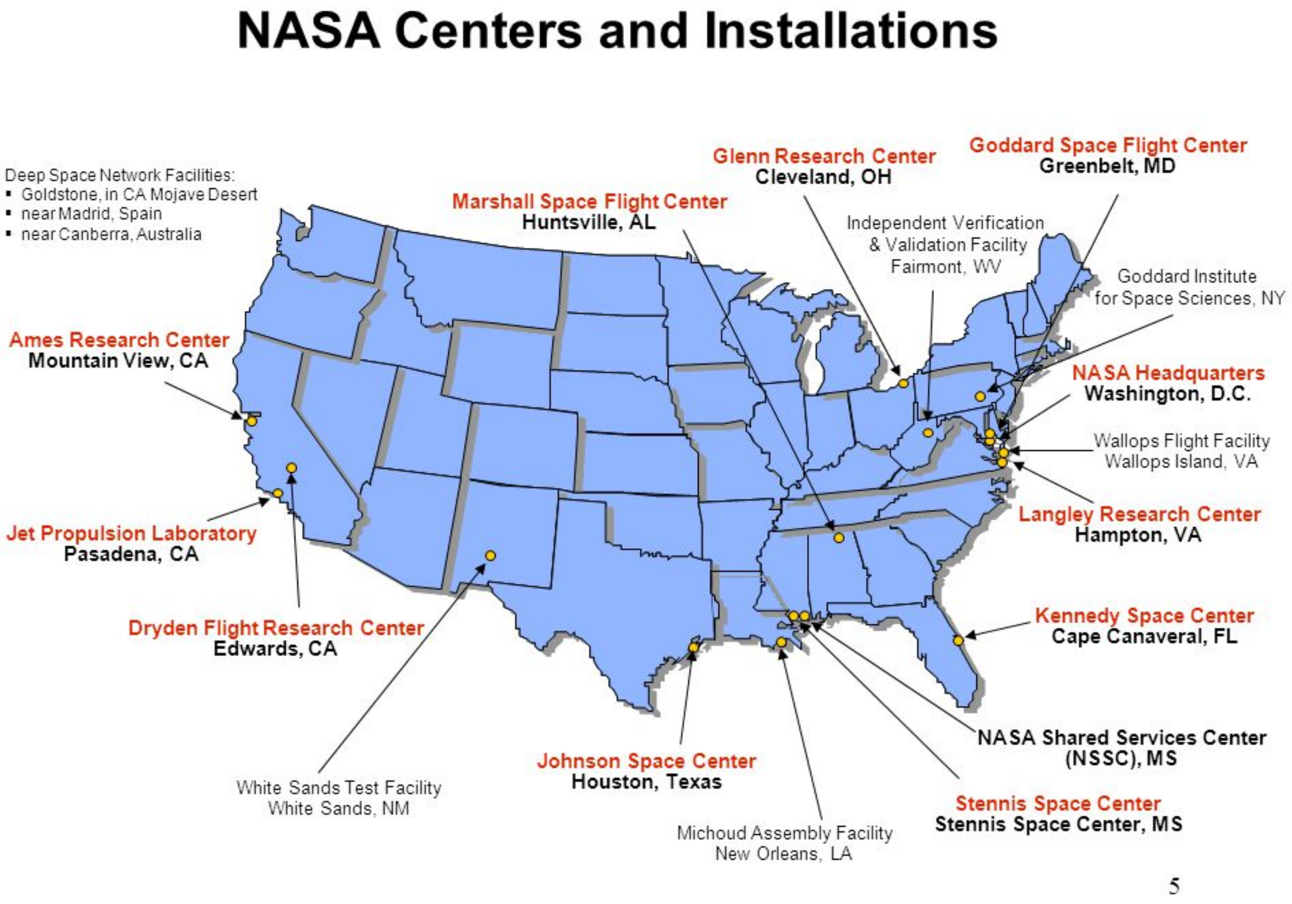
NASA Internship Programs

- 200 + Marshall Interns
- 3 Academies
- 30 Academy Inters

- Space Hardware and Robotics Academy – 4 Project Groups
- Propulsion Academy – 3 Project Groups
- Leadership Academy – Single Inter Projects

NASA Leadership Academy

- Single Intern Research Projects
- Weekly NASA Director Chats
- Weekly Team Building Activities
- Trips to NASA Centers



NASA Leadership Academy Trips

Michoud Assembly Facility

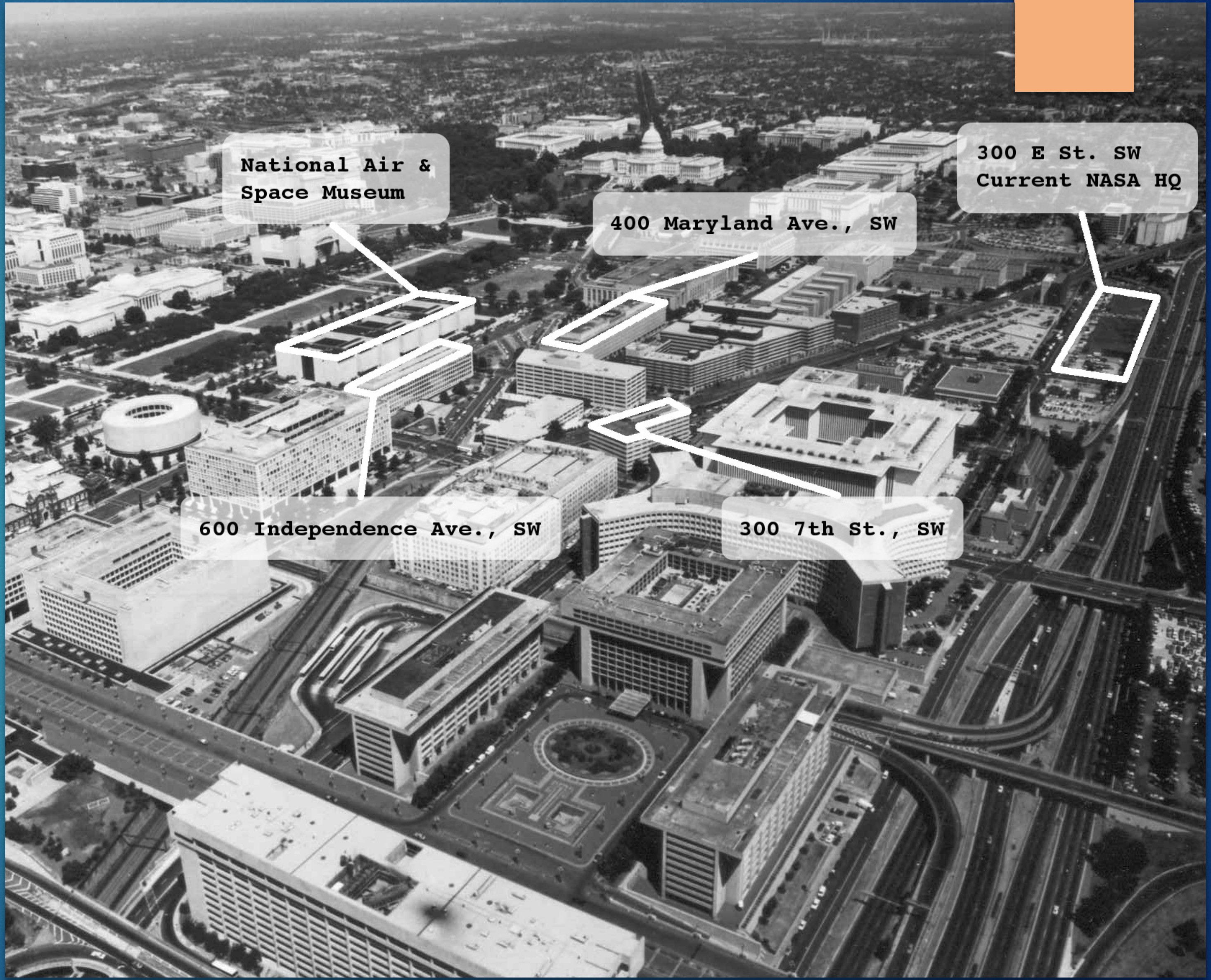
- New Orleans, Louisiana
- 43+ acre Manufacturing Building
- Manufactured Flight Hardware

Goddard Space Flight Center

- Greenbelt, Maryland
- 10,000 Civil Servants & Contractors
- James Webb Space Telescope (JWST)
- Transiting Exoplanet Survey Satellite (TESS)
- Satellite Servicing Project

NASA Headquarters

- Science Mission Director
- Human Exploration and Operations Mission Director
- Space Technology Mission Director
- Aeronautics Research Mission Director



Research Projects

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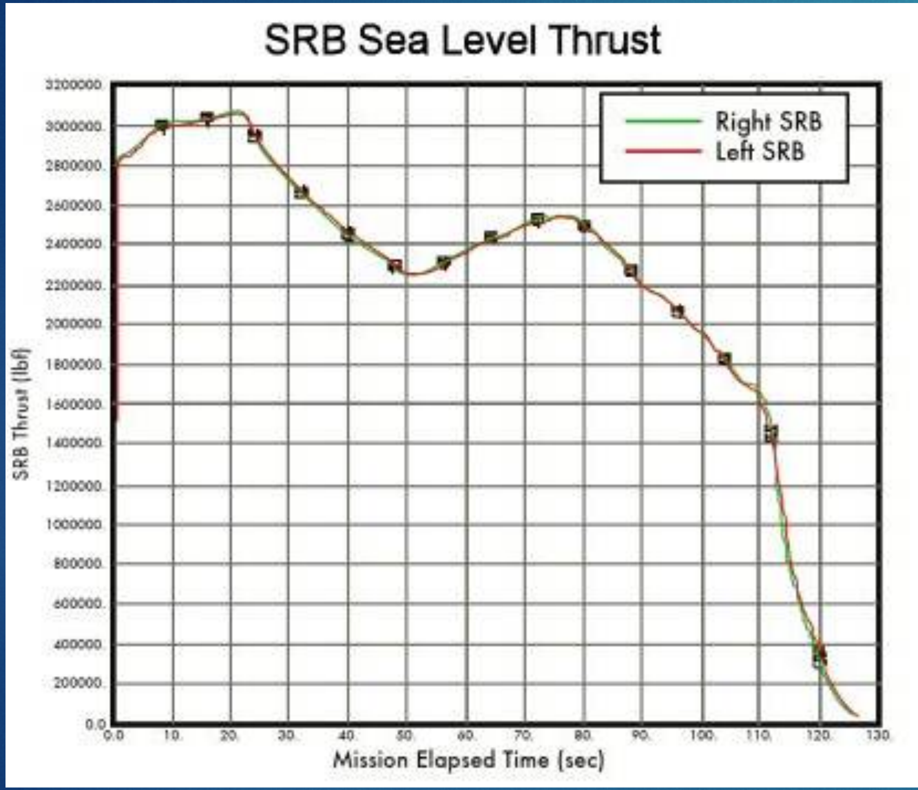
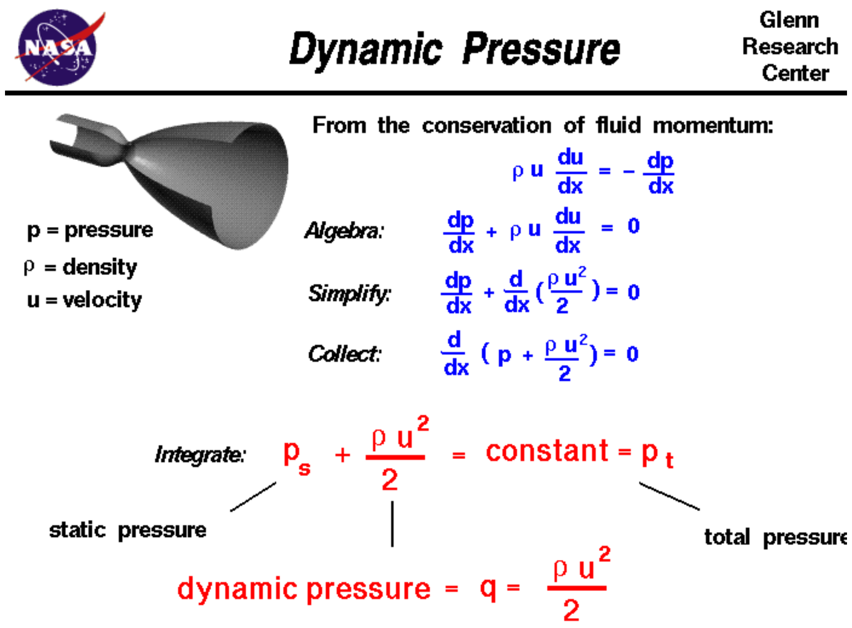
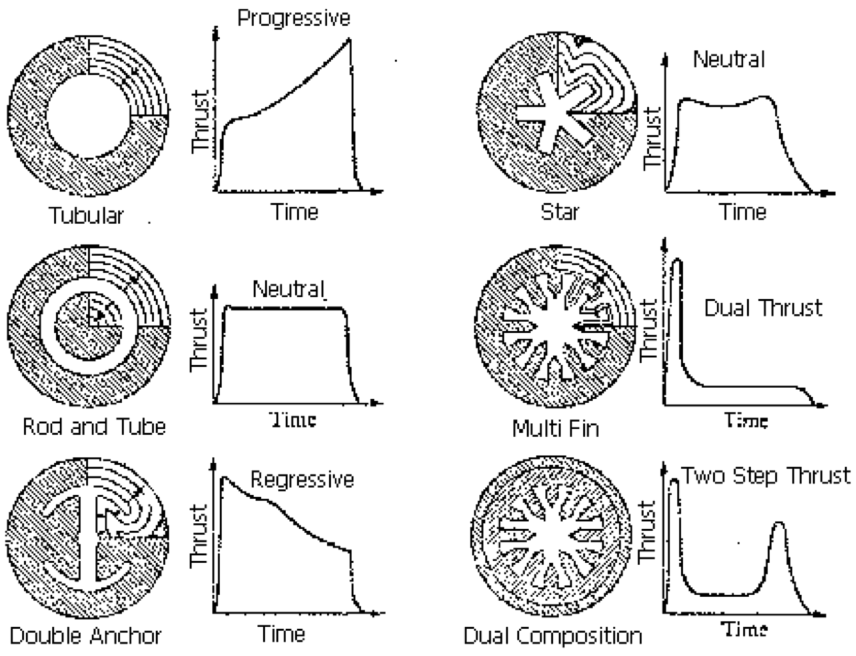
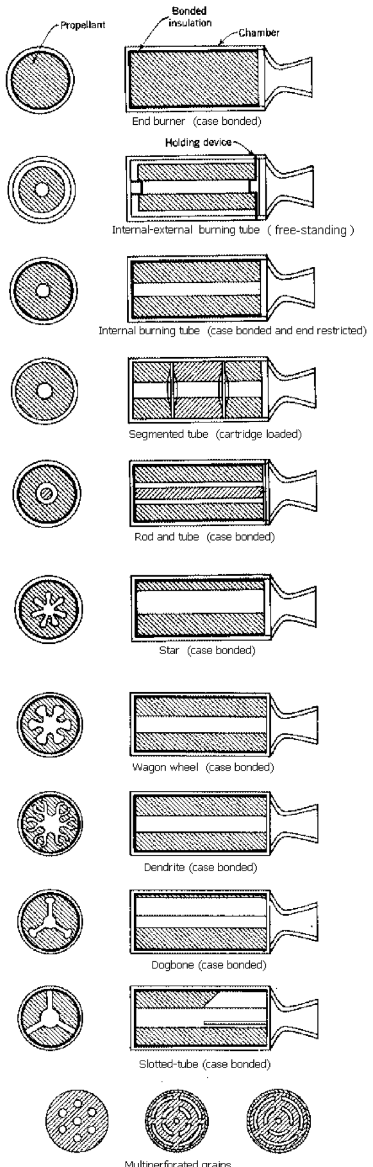
Background


SRB Sea Level Thrust
Right SRB
Left SRB
SRB Thrust (lbf)
Mission Elapsed Time (sec)

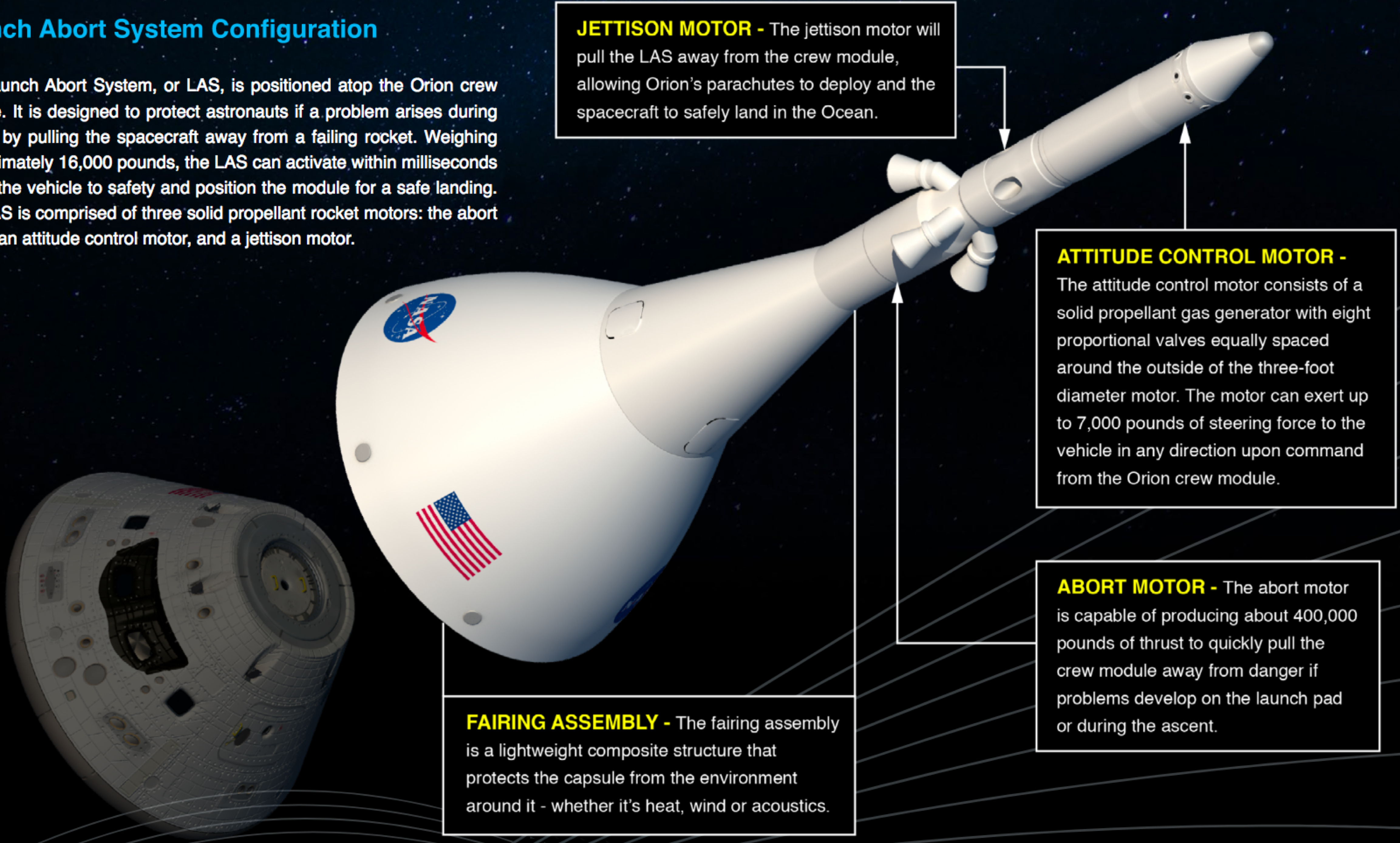

Dynamic Pressure
Glenn Research Center
From the conservation of fluid momentum:
p = pressure
ρ = density
u = velocity
Algebra:
Simplify:
Collect:
Integrate:
static pressure
total pressure
dynamic pressure = q =


Progressive
Tubular
Thrust
Time
Neutral
Star
Rod and Tube
Multi Fin
Dual Thrust
Regressive
Double Anchor
Two Step Thrust
Dual Composition


Propellant
Bonded insulation
Chamber
End burner (case bonded)
Holding device
Internal-external burning tube (free-standing)
Internal burning tube (case bonded and end restricted)
Segmented tube (cartridge loaded)
Rod and tube (case bonded)
Star (case bonded)
Wagon wheel (case bonded)
Dendrite (case bonded)
Dogbone (case bonded)
Slotted-tube (case bonded)

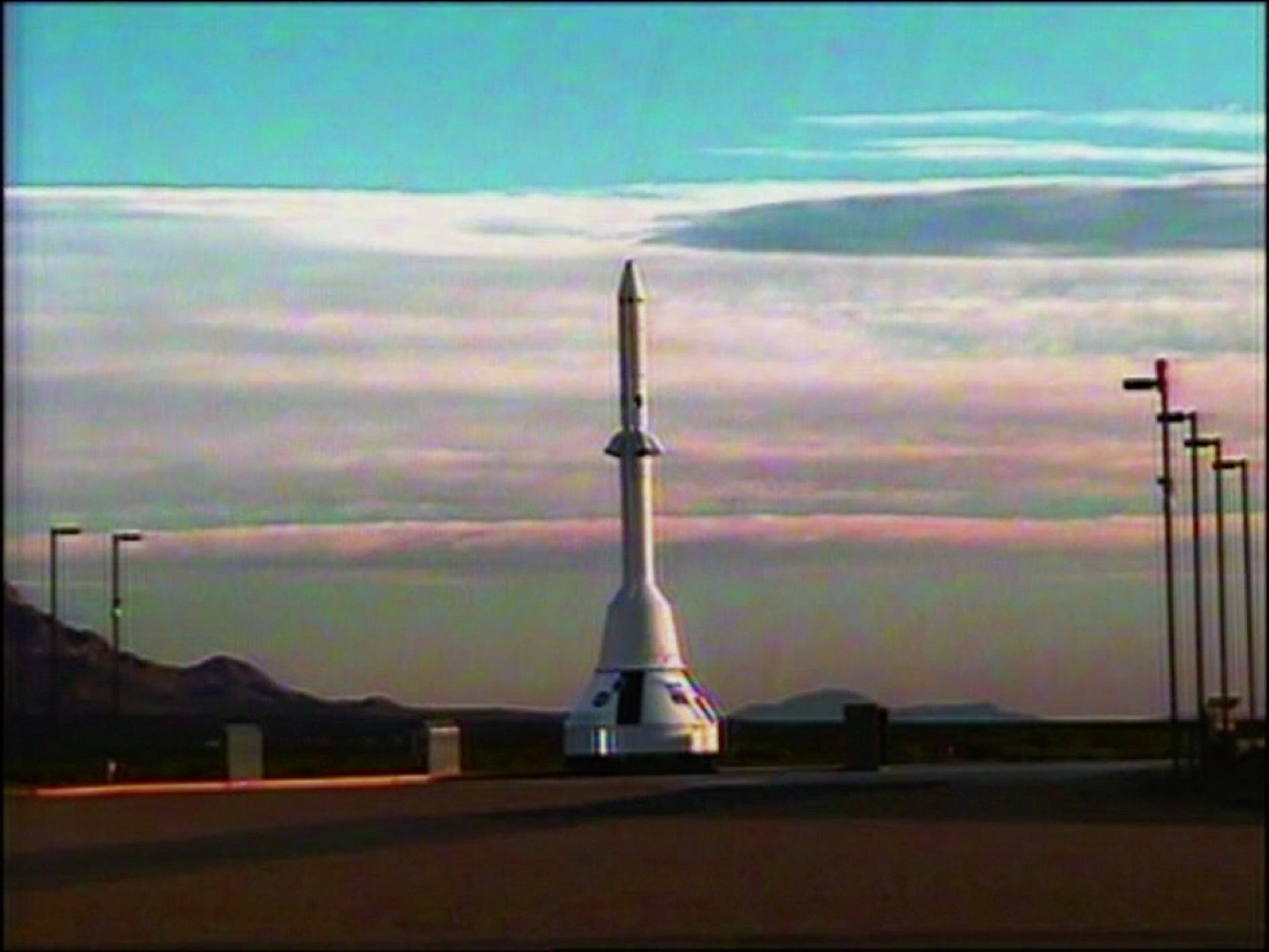
Launch Abort System Configuration

The Launch Abort System, or LAS, is positioned atop the Orion crew module. It is designed to protect astronauts if a problem arises during launch by pulling the spacecraft away from a failing rocket. Weighing approximately 16,000 pounds, the LAS can activate within milliseconds to pull the vehicle to safety and position the module for a safe landing. The LAS is comprised of three solid propellant rocket motors: the abort motor, an attitude control motor, and a jettison motor.



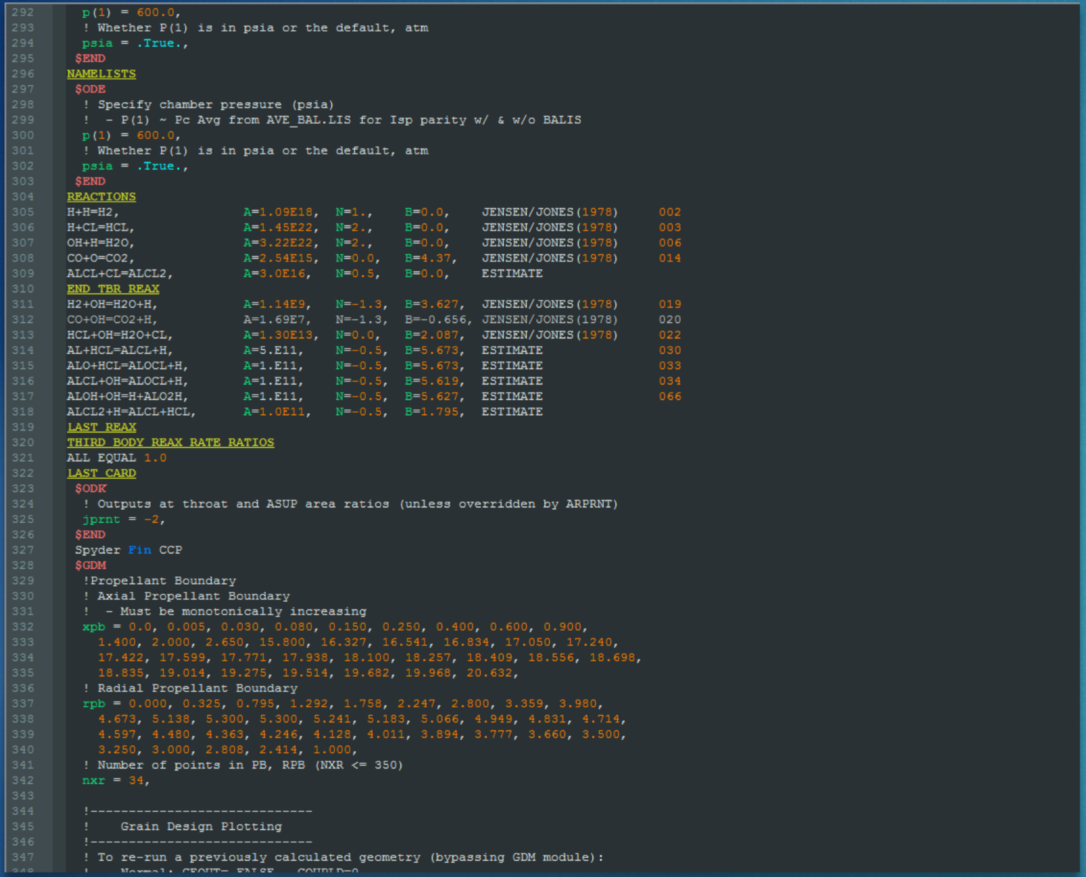
Launch Abort System

- Abort Motor
- Attitude Control Motor
- Jettison Motor
- Parachutes

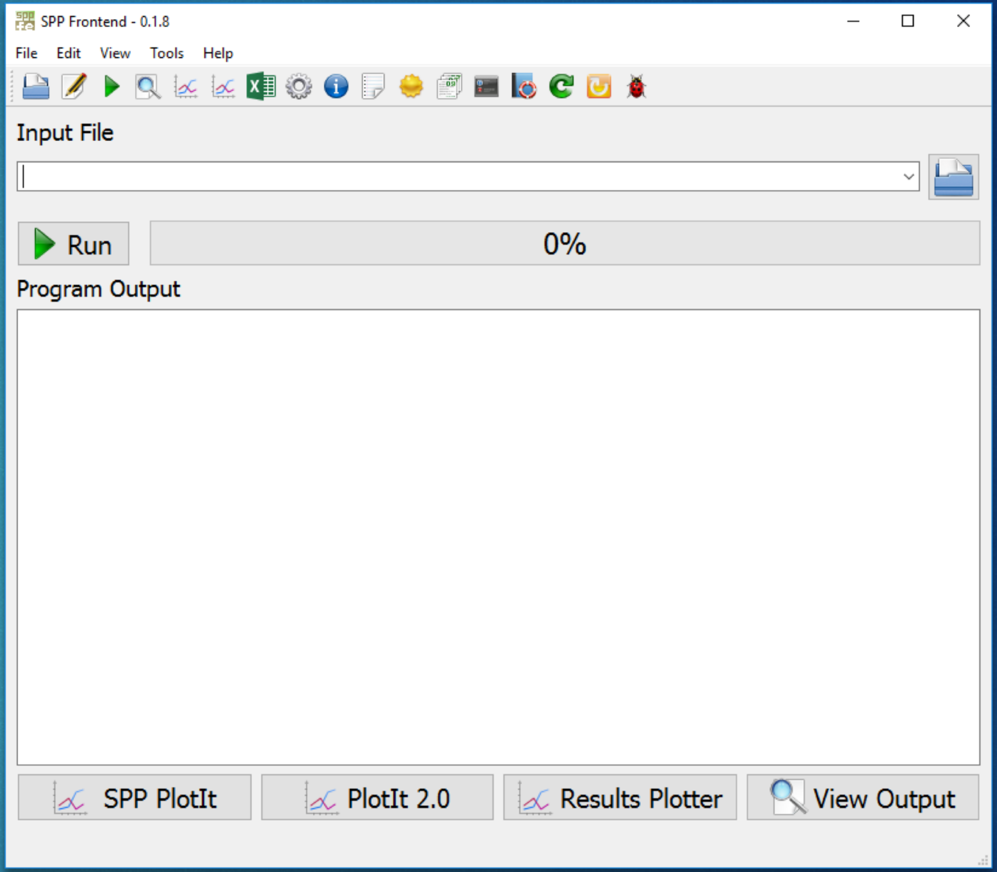


Solid Performance Program (SPP)

- Fortran based software
- 40+ years of development
- Shorter runtime

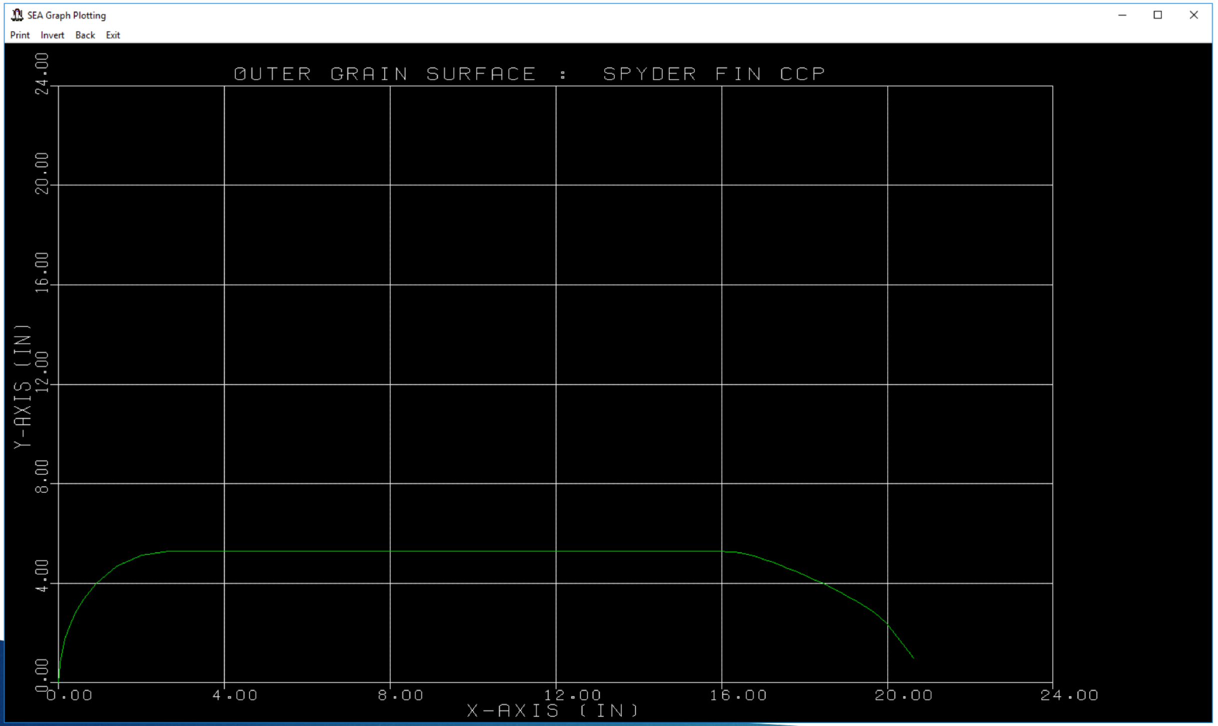


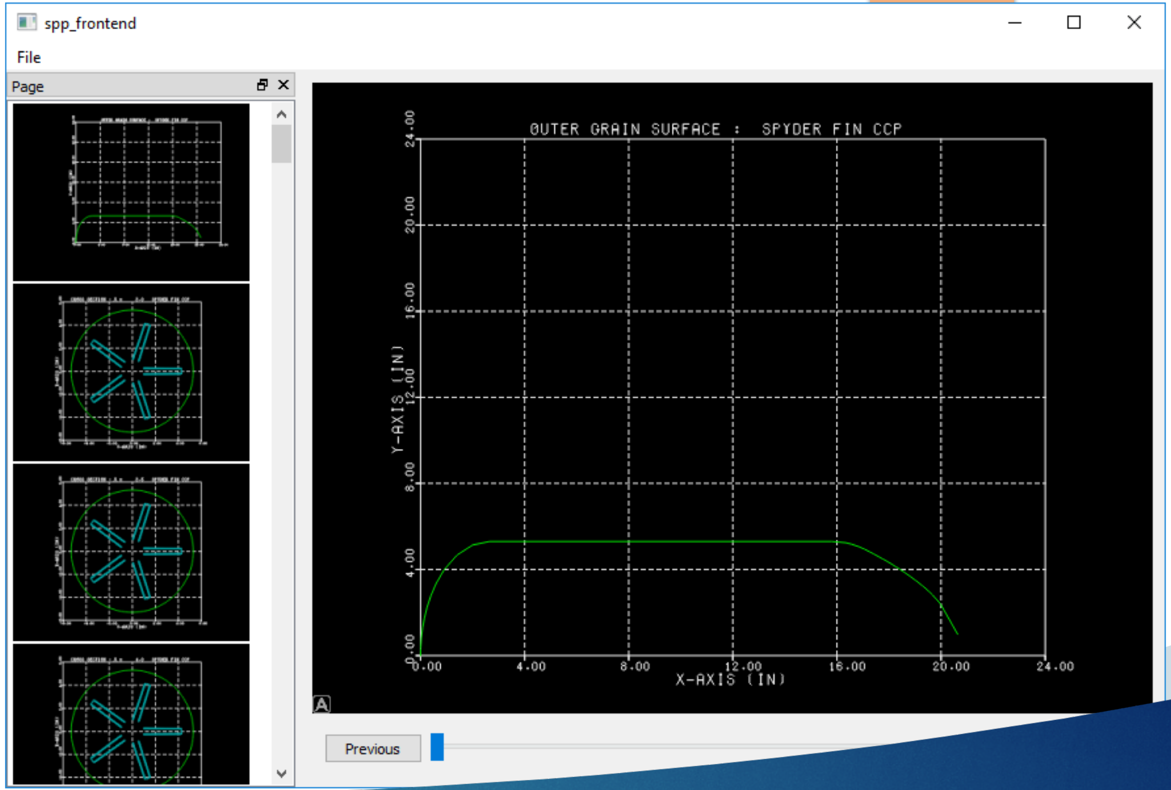
```
    p(1) = 600.0,
    ! Whether P(1) is in psia or the default, atm
    psia = .True.,
   $END
  NAMELISTS
   $ODE
    ! Specify chamber pressure (psia)
    !  - P(1) ~ Pc Avg from AVE_BAL.LIS for Isp parity w/ & w/o BALIS
    p(1) = 600.0,
    ! Whether P(1) is in psia or the default, atm
    psia = .True.,
   $END
  REACTIONS
  H+H=H2,                 A=1.09E18,  N=1.,    B=0.0,    JENSEN/JONES(1978)    002
  H+CL=HCL,               A=1.45E22,  N=2.,    B=0.0,    JENSEN/JONES(1978)    003
  OH+H=H2O,               A=3.22E22,  N=2.,    B=0.0,    JENSEN/JONES(1978)    006
  CO+O=CO2,               A=2.54E15,  N=0.0,   B=4.37,   JENSEN/JONES(1978)    014
  ALCL+CL=ALCL2,          A=3.0E16,   N=0.5,   B=0.0,    ESTIMATE
  END TBR REAX
  H2+OH=H2O+H,            A=1.14E9,   N=-1.3,  B=3.627,  JENSEN/JONES(1978)    019
  CO+OH=CO2+H,            A=1.69E7,   N=-1.3,  B=-0.656, JENSEN/JONES(1978)    020
  HCL+OH=H2O+CL,          A=1.30E13,  N=0.0,   B=2.087,  JENSEN/JONES(1978)    022
  AL+HCL=ALCL+H,          A=5.E11,    N=-0.5,  B=5.673,  ESTIMATE              030
  ALO+HCL=ALOCL+H,        A=1.E11,    N=-0.5,  B=5.673,  ESTIMATE              033
  ALCL+OH=ALOCL+H,        A=1.E11,    N=-0.5,  B=5.619,  ESTIMATE              034
  ALOH+OH=H+ALO2H,        A=1.E11,    N=-0.5,  B=5.627,  ESTIMATE              066
  ALCL2+H=ALCL+HCL,       A=1.0E11,   N=-0.5,  B=1.795,  ESTIMATE
  LAST REAX
  THIRD BODY REAX RATE RATIOS
  ALL EQUAL 1.0
  LAST CARD
   $ODK
    ! Outputs at throat and ASUP area ratios (unless overridden by ARPRNT)
    jprnt = -2,
   $END
   Spyder Fin CCP
   $GDM
    !Propellant Boundary
    ! Axial Propellant Boundary
    !  - Must be monotonically increasing
    xpb = 0.0, 0.005, 0.030, 0.080, 0.150, 0.250, 0.400, 0.600, 0.900,
      1.400, 2.000, 2.650, 15.800, 16.327, 16.541, 16.834, 17.050, 17.240,
      17.422, 17.599, 17.771, 17.938, 18.100, 18.257, 18.409, 18.556, 18.698,
      18.835, 19.014, 19.275, 19.514, 19.682, 19.968, 20.632,
    ! Radial Propellant Boundary
    rpb = 0.000, 0.325, 0.795, 1.292, 1.758, 2.247, 2.800, 3.359, 3.980,
      4.673, 5.138, 5.300, 5.300, 5.241, 5.183, 5.066, 4.949, 4.831, 4.714,
      4.597, 4.480, 4.363, 4.246, 4.128, 4.011, 3.894, 3.777, 3.660, 3.500,
      3.250, 3.000, 2.808, 2.414, 1.000,
    ! Number of points in PB, RPB (NXR <= 350)
    nxr = 34,

    !-----------------------------
    !    Grain Design Plotting
    !-----------------------------
    ! To re-run a previously calculated geometry (bypassing GDM module):
```



Input File

Existing Frontend GUI



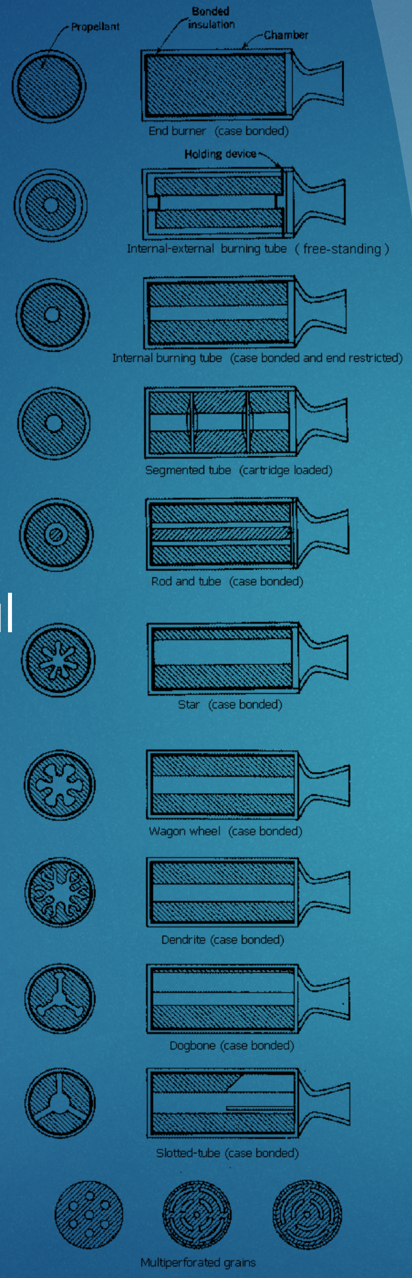


SPP Plotting Tool

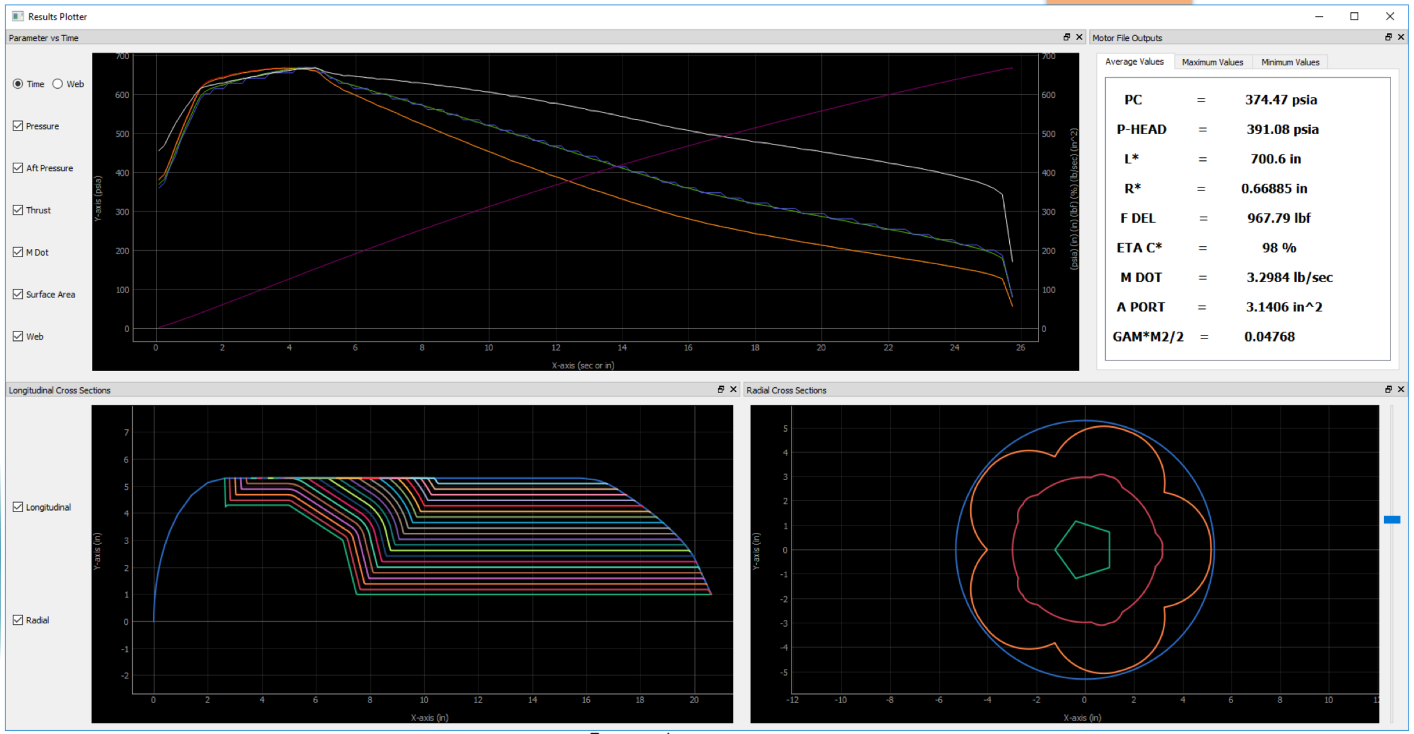
Existing Tool

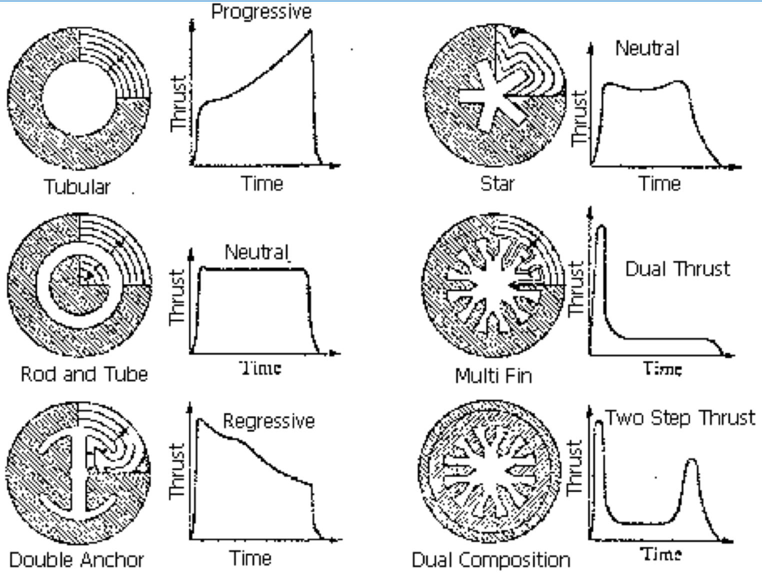
Results

- Multiple plotting tools
- Radial and Longitudinal
- Displays motor results



Ref. Hill & Peterson, Mechanics and Thermodynamics of Propulsion





Acknowledgements

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Questions?