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SUPAERO

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MASS ESTIMATING AND STRUCTURE SIZING OF A REUSABLE LUNAR LAUNCHER

Presentation of Progress - Research Project

Master of Science in Aerospace Engineering

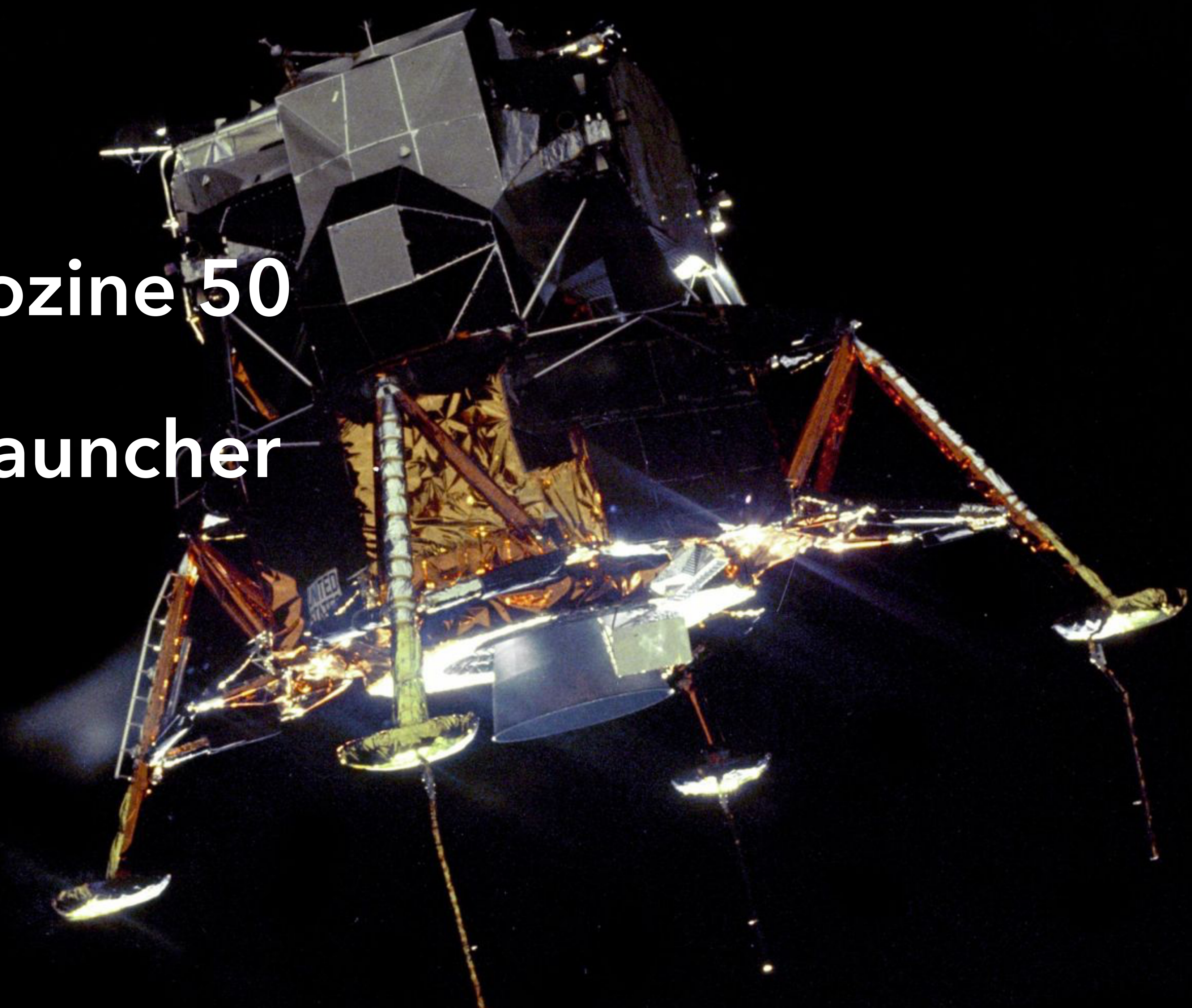
1. PROJECT'S GOAL

A NEW NEED

- Design a reusable launcher which will act as a shuttle

2. STATE OF THE ART

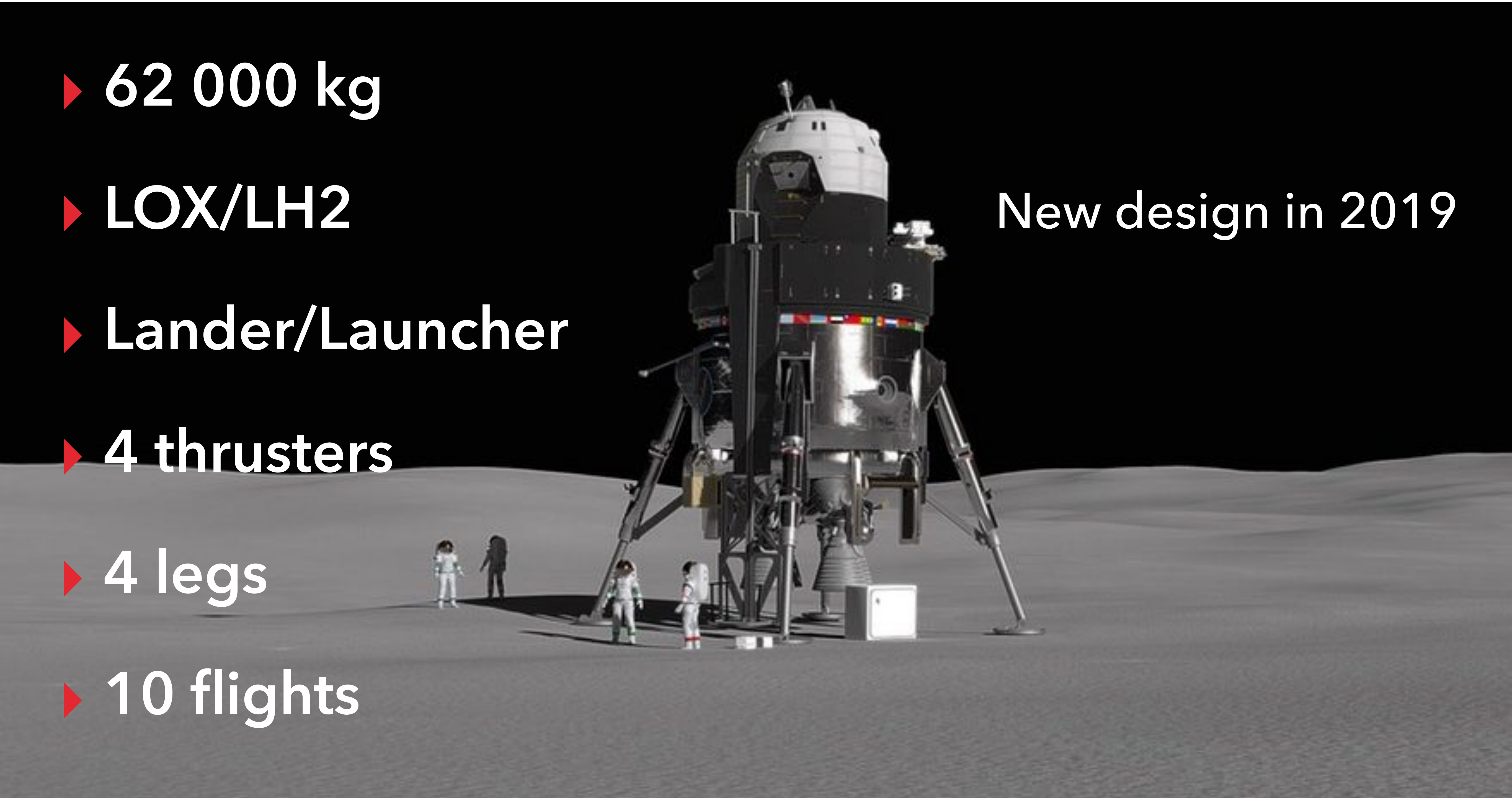
NASA – APOLLO LUNAR MODULE (1969)



- 15 200 kg
- N2O4/Aerozine 50
- Lander & Launcher
- 1 thruster
- 4 legs

LOCKHEED MARTIN (2018)

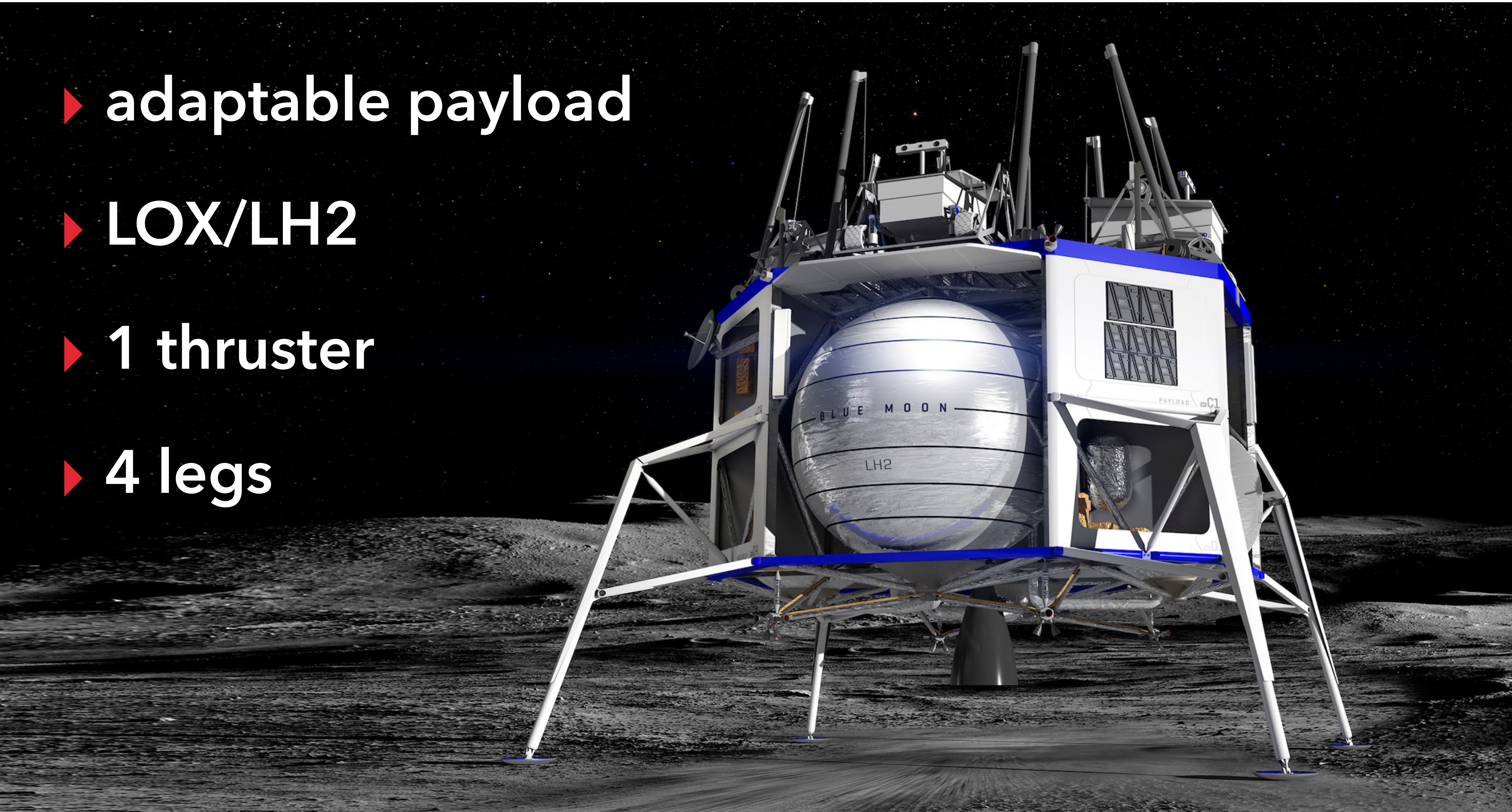
- 62 000 kg
- LOX/LH2
- Lander/Launcher
- 4 thrusters
- 4 legs
- 10 flights



New design in 2019

BLUE ORIGIN – BLUE MOON (2019)

- adaptable payload
- LOX/LH2
- 1 thruster
- 4 legs



NEW SPACE

ispace

MOON EXPRESS

Google LUNAR XPRIZE

SPACEIL

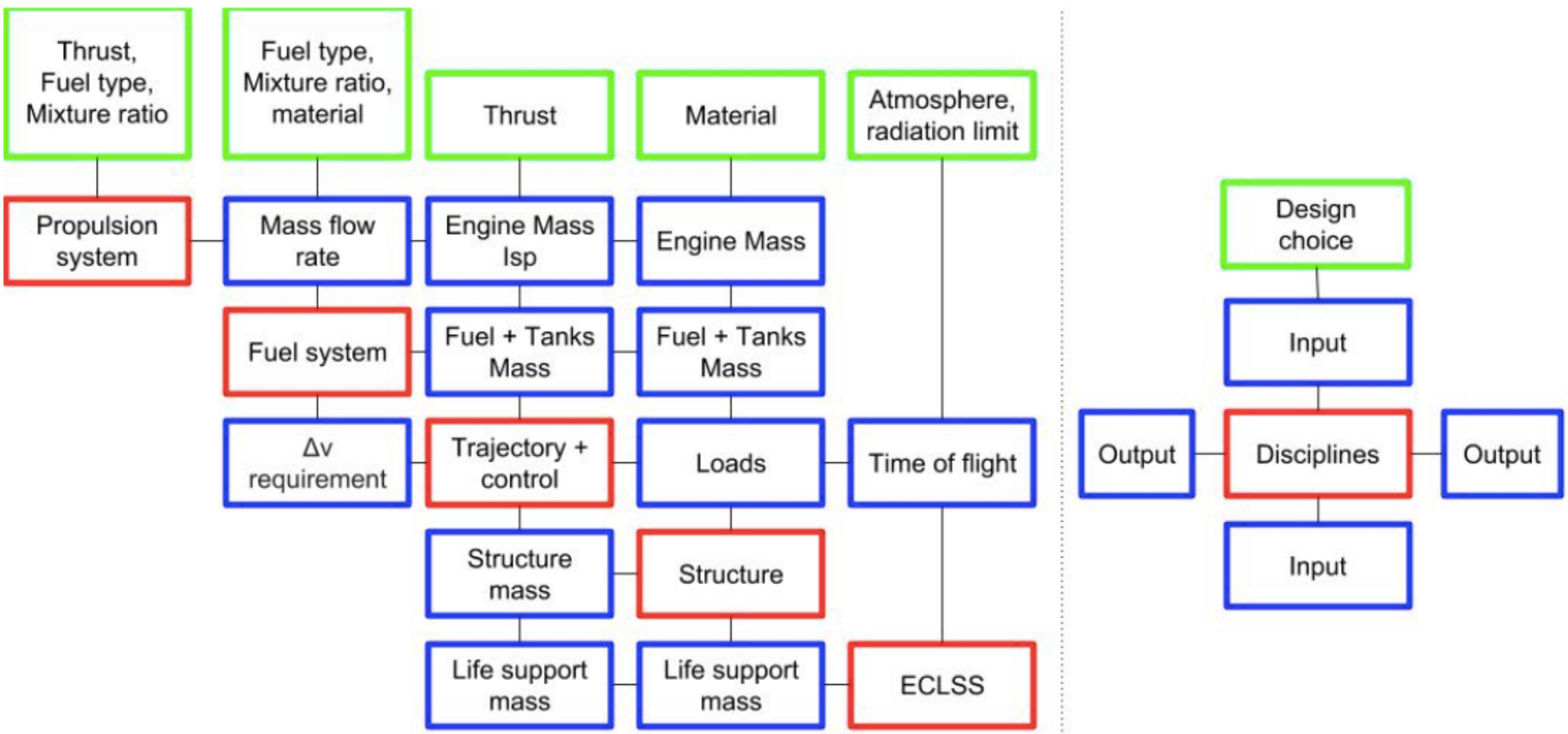
ASTROBOTIC

DESIGN CHOICES

- LOX/LH2
- 4 legs
- Truss configuration

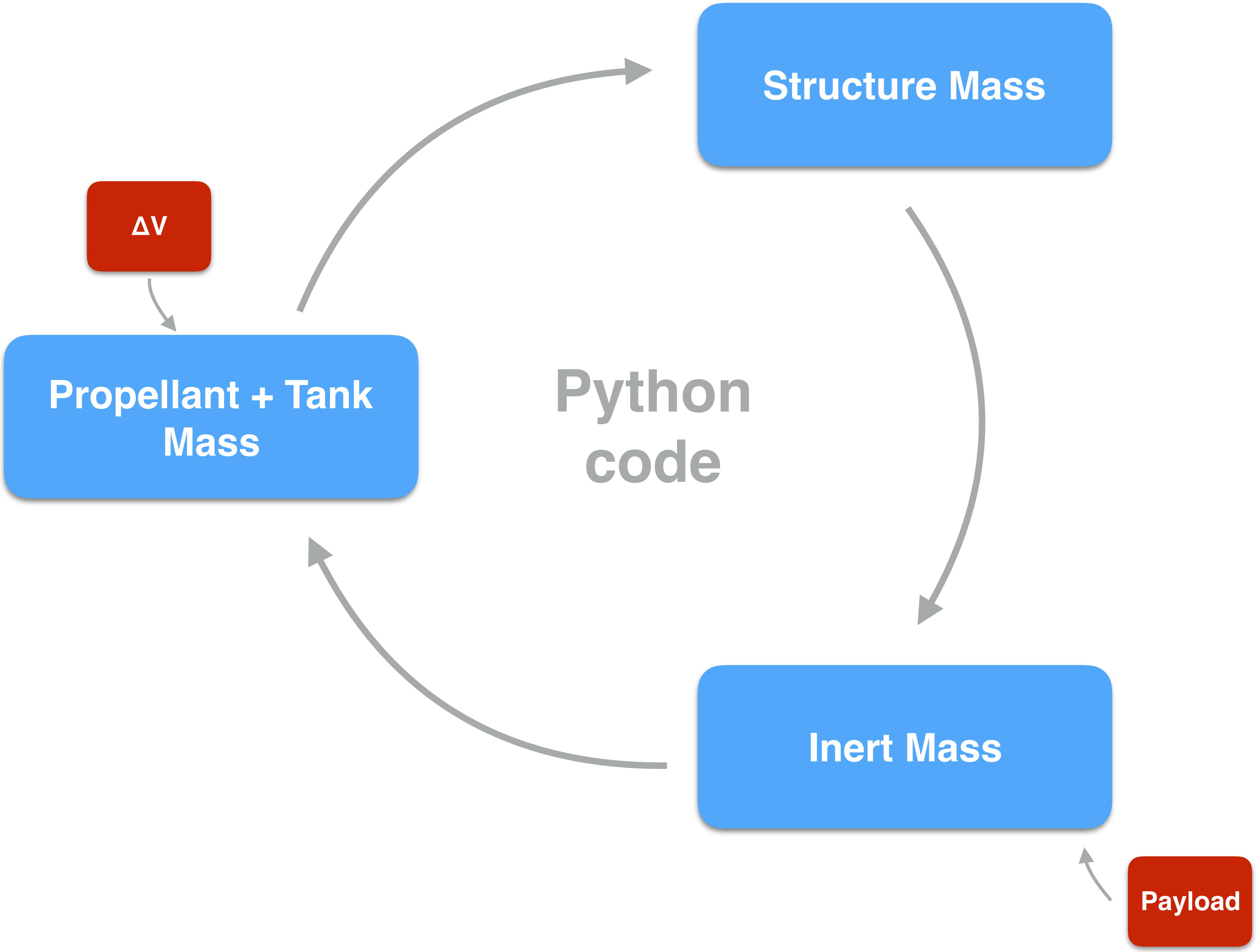
3. MY WORK

MDO STRUCTURE



[1] L. Beauregard, *Project Presentation,* 2019

WHAT I'M WORKING ON



ISP & FUEL MASS

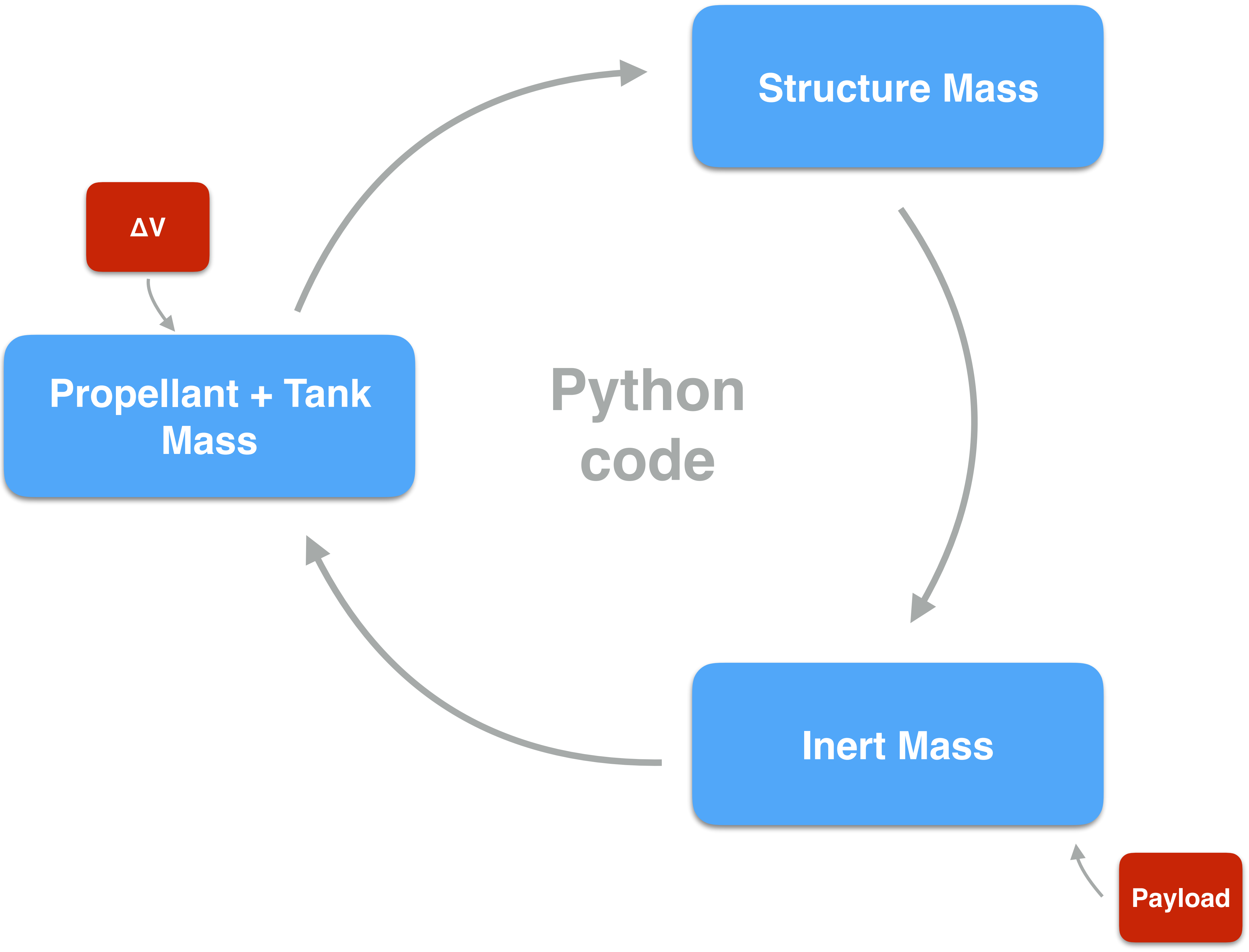
$$\Delta v = I_{sp} g_0 \ln\left(\frac{M_{tot}}{M_{inert}}\right) \quad \longrightarrow \quad \frac{M_{tot}}{M_{inert}} = \exp\left(\frac{\Delta v}{I_{sp} g_0}\right)$$

[2] William Moore, *Treatise on the Motion of Rockets,* 1813

FUEL REPARTITION AND TANKS MASS

```
# computation of propellant and tank mass
def propellant_and_tank(deltav, M_tot, M_inert):

    # rocket equation
    R = exp(deltav / (I_sp * g))

    M_tot = M_inert * R
    M_prop = M_tot - M_inert

    M_prop = M_prop * 1.07 # 4% for FPR Propellant, 3% for Unusable Propellant

    # mixture ratio LOX/LH2, 6:1
    M_LH2 = M_prop / 7
    M_LOX = 6 * (M_prop / 7)
    M_LH2_1 = M_LH2 / 2  # 2 tanks for mass distribution
    M_LOX_1 = M_LOX / 2  # 2 tanks for mass distribution

    # LOX Tank
    M_LOX_Tank = 0.00152 * M_LOX_1 + 318
    V_LOX_Tank = M_LOX_1 / rho_LOX
    r_LOX_Tank = (V_LOX_Tank / (4 * pi /3))**(1 / 3)  # radius of LOX tank
    A_LOX_Tank = 4 * pi * (r_LOX_Tank**2)  # Area LOX Tank
    M_LOX_Insu = 1.123 * A_LOX_Tank  # Mass LOX insulation
    M_LOX_Tanks = 2 * M_LOX_Tank
    M_LOX_Insus = 2 * M_LOX_Insu
```

[3] David L. Akin, Mass Estimating Relationships, 2005

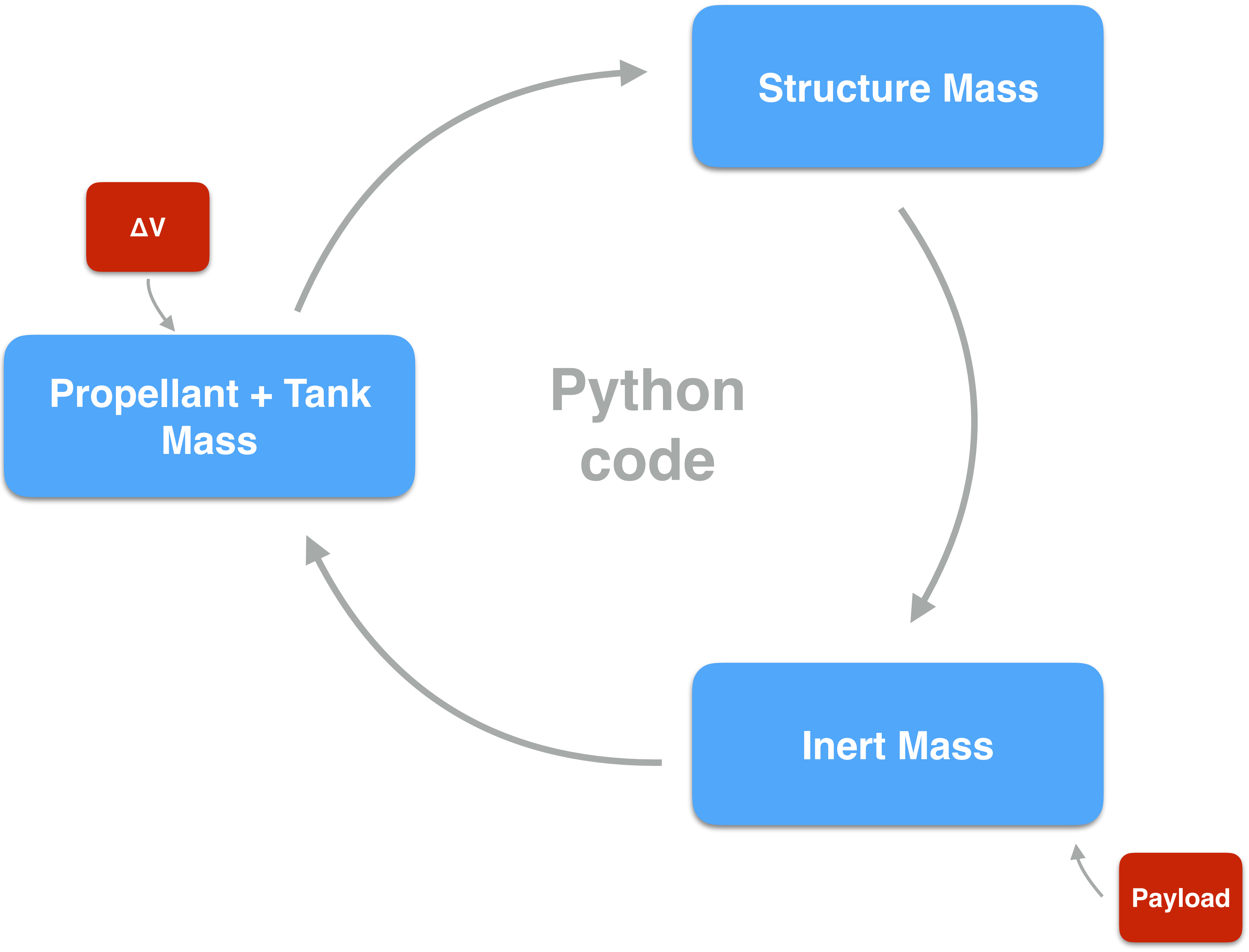

Structure Mass
ΔV
Propellant + Tank Mass
Python code
Inert Mass
Payload

STRUCTURE ANALYSIS

- Geometry
- Meshing

Nastran

- Analysis
- Output as new Input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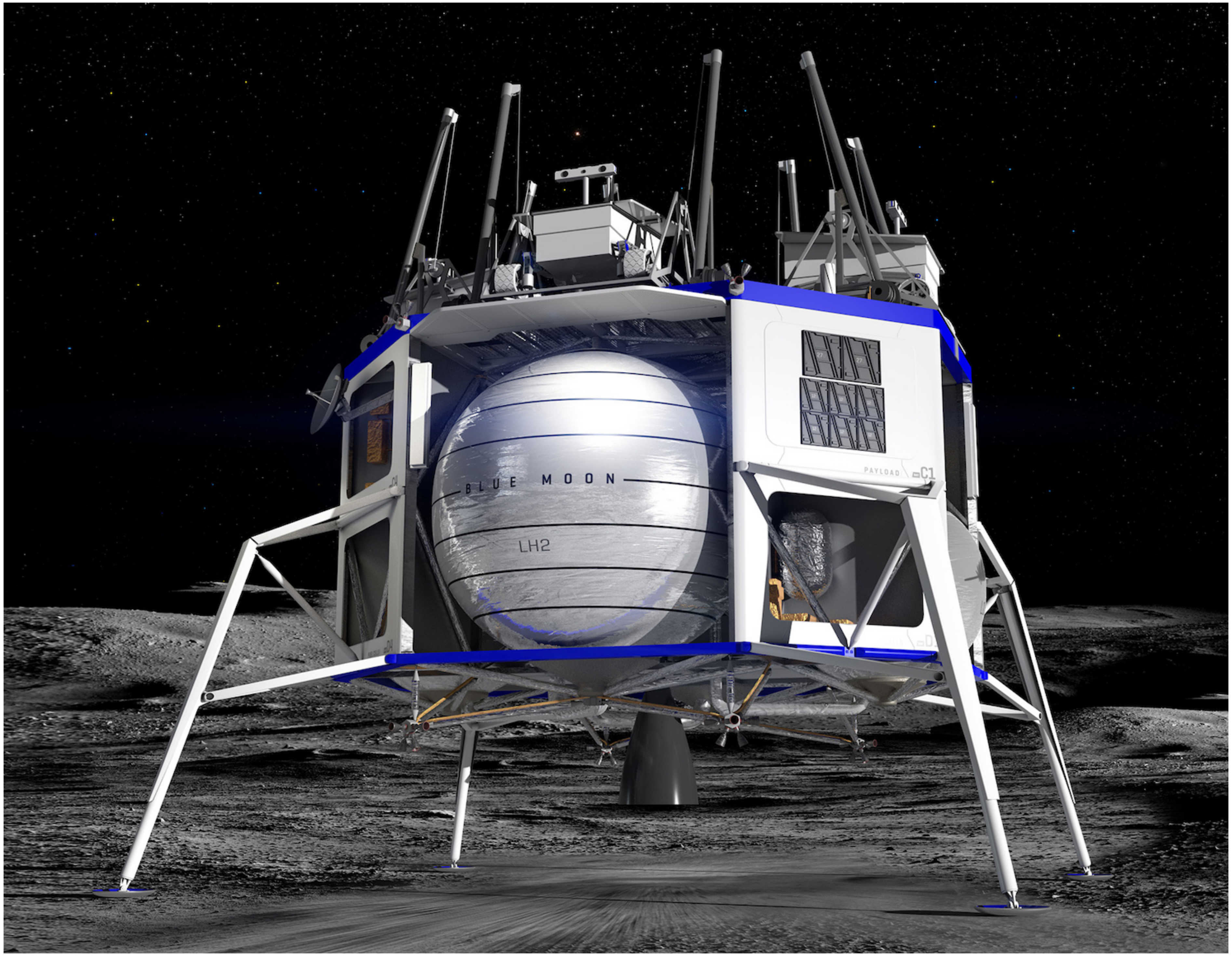
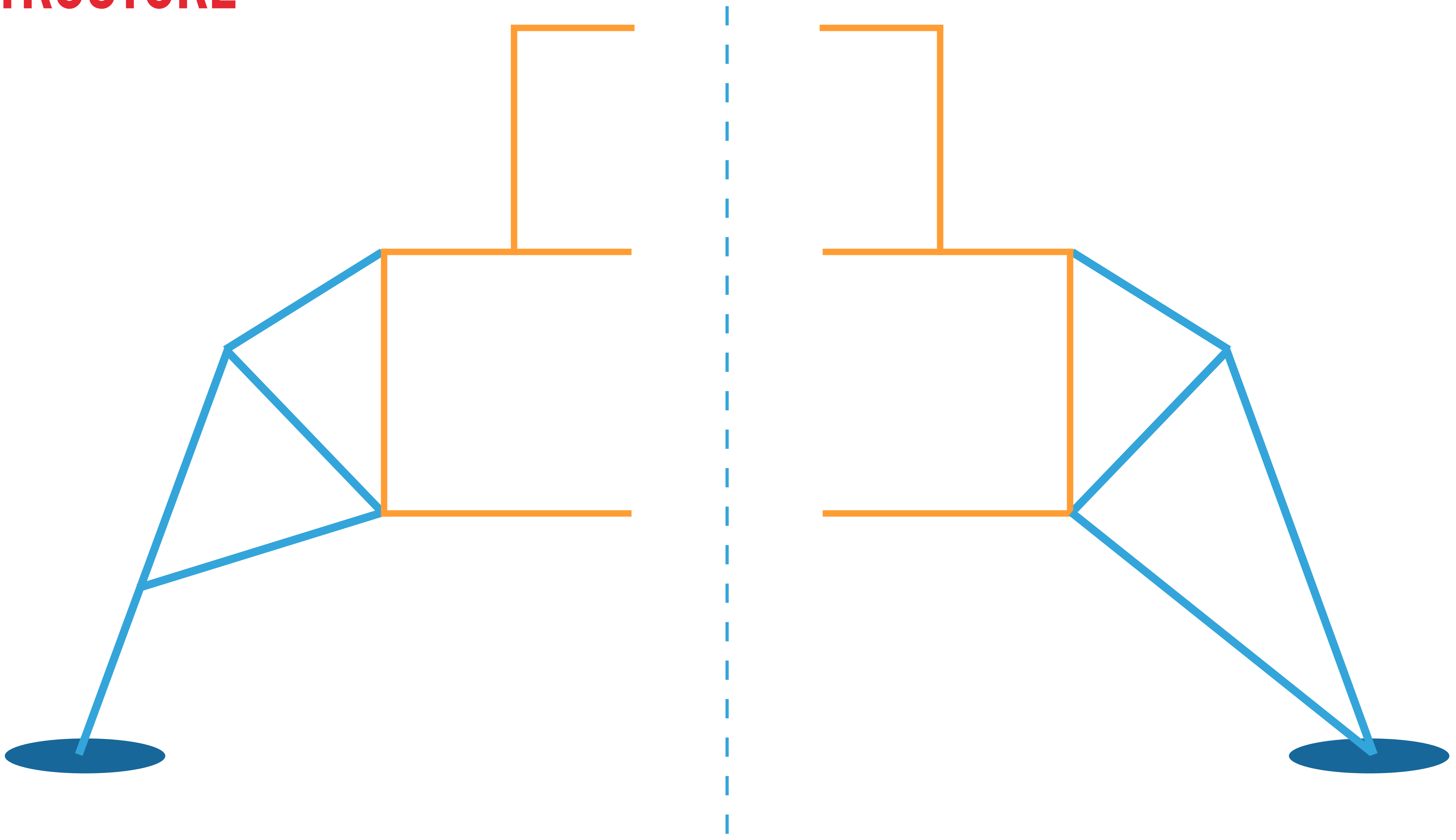
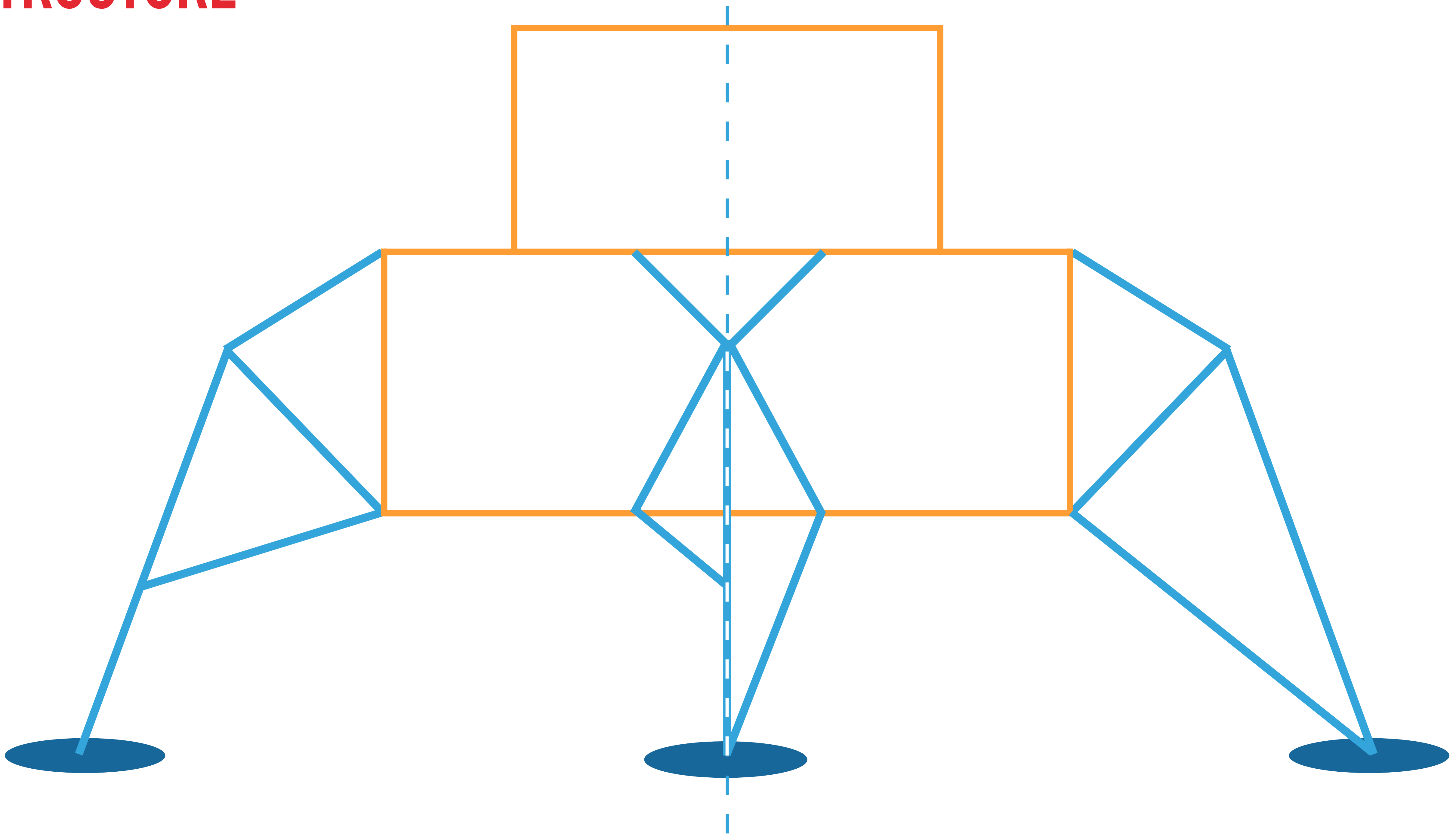


STRUCTURE



STRUCTURE



4. 1ST RESULTS

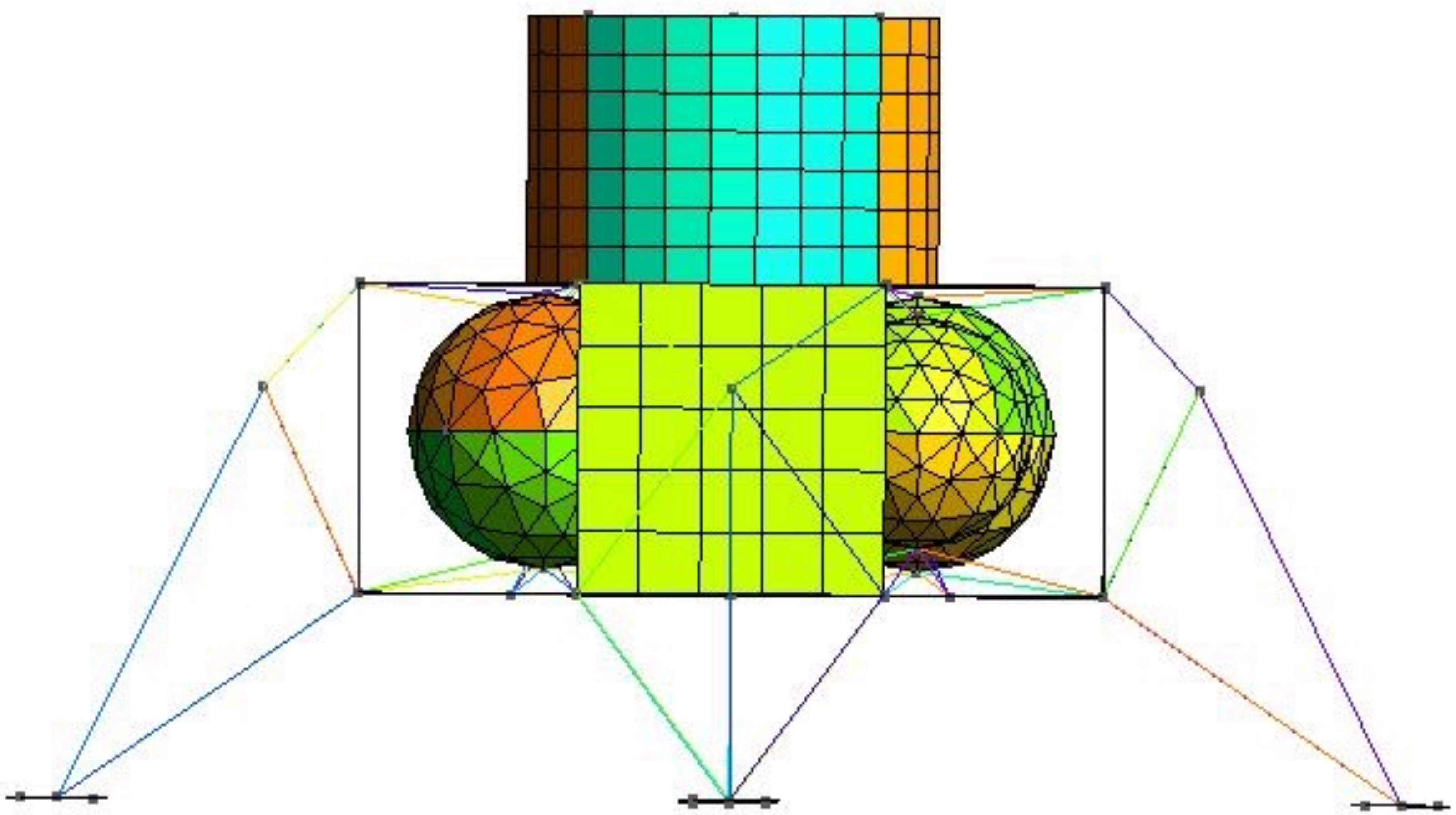
MASS

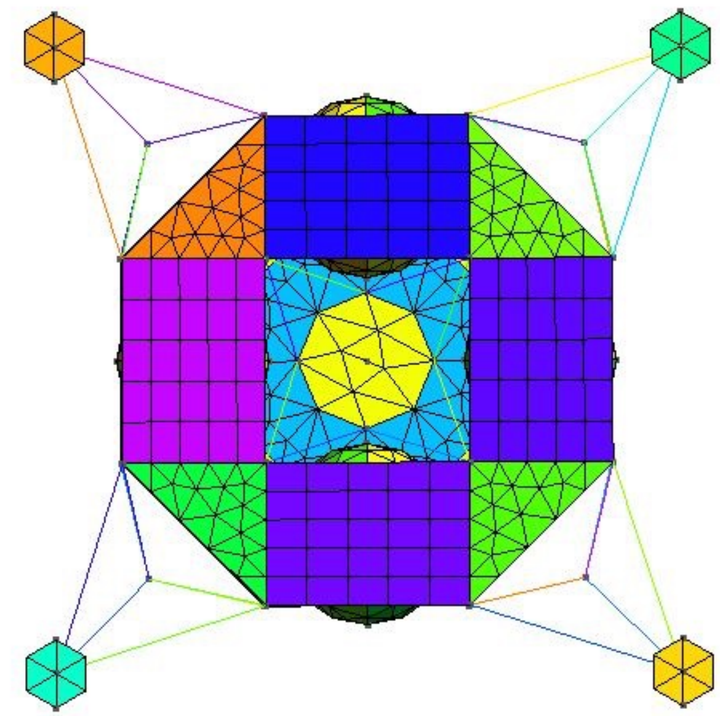
Delta V, Ascent	0	*2.28
Payload, Ascent	0	6,000
Delta V, Descent	2.10	2.10
Payload, Descent	25,000	6,000
Total Inert Mass	9,823	9,823
Structure	1,681	1,681
Engines	822	822
RCS Dry	411	411
Landing Syst.	784	784
Thermal Prot.	2,017	2,017
Tanks	3,025	3,025
DMS (GN&C)	150	150
** Elect. Power	478	478
Airlock/Tunnel	455	455
Total Prop. Mass	25,251	32,395
Ascent Prop.	0	11,334
Descent Prop.	22,597	18,137
Unusable Prop.(3%)	678	884
FPR Prop. (4%)	904	1,179
Usable RCS	858	689
Unusable RCS (5%)	43	34
FPR (20%)	172	138
Deorbit or Gross	60,074	48,218

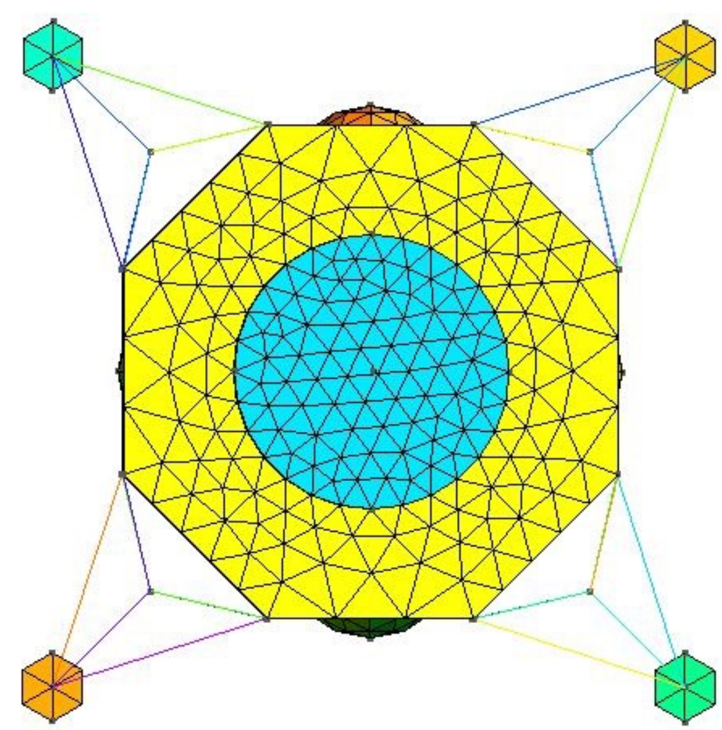
- Delta V = 4380 m/s
- BlackBox = 10333 kg
- Inert Mass = 9062 kg
- Structure = 2122 kg
- Tanks Mass = 1906 kg
- Prop. Mass = 27352 kg
- Total Mass = 42415 kg

[4] NASA, Lunar Lander Conceptual Design, 1988

GMSH







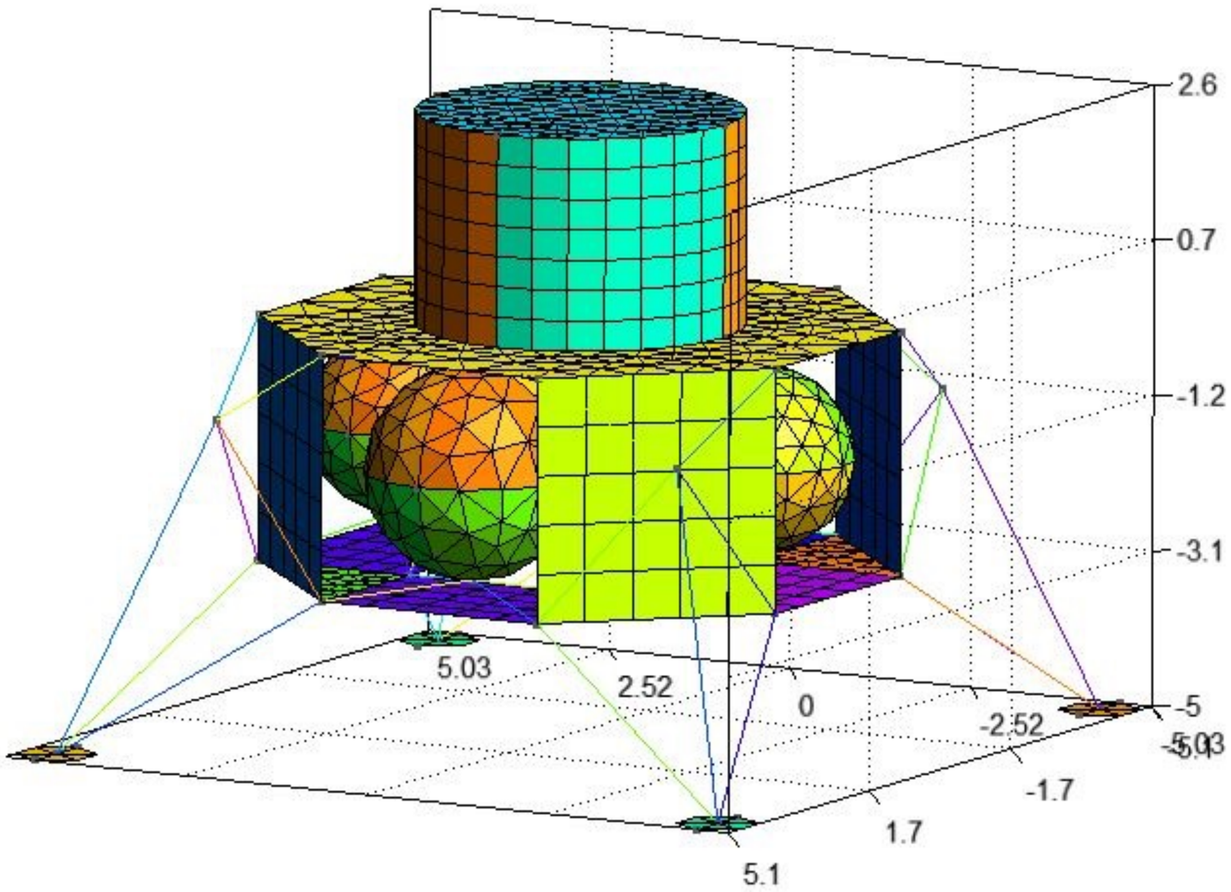
5. DEMO

Tool demonstration

6. STILL TO BE DONE

NASTRAN PART

- Masses
- Elements' properties
- Loads
- Boundary conditions
- Initialization
- Optimization loops



THANK YOU FOR YOUR ATTENTION

SPECIAL THANKS TO:

JOSEPH MORLIER
LAURENT BEAUREGARD
JOAN MAS COLOMER

REFERENCES

[1] L. Beauregard, *Project Presentation,* 2019

[2] William Moore, *Treatise on the Motion of Rockets,* 1813

[3] David L. Akin, Mass Estimating Relationships, 2005

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[1] NASA. *Lunar Lander Conceptual Design*, 1988.

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