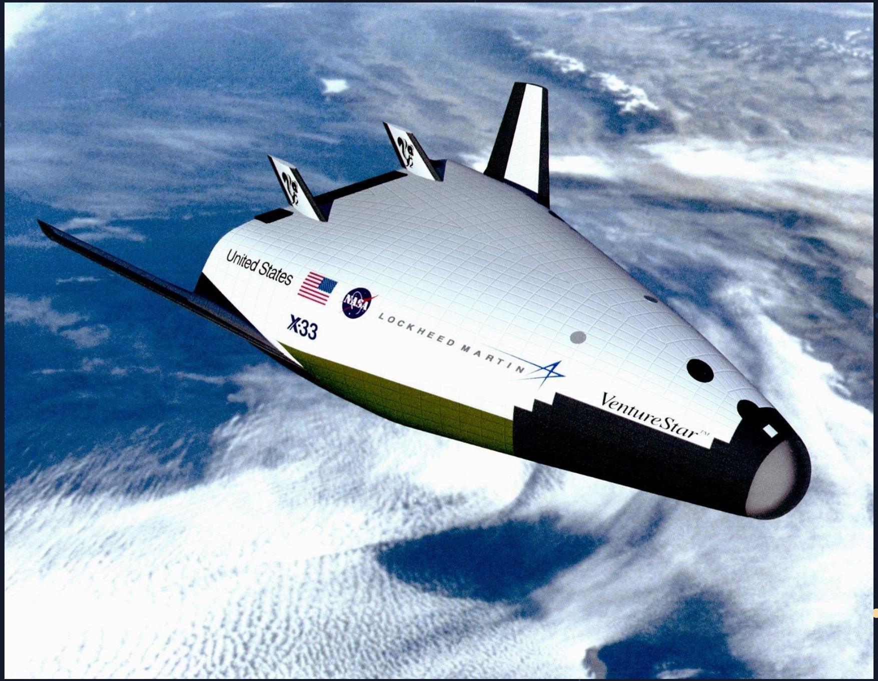
Blast Off!

Lecture 4

SSTO

Single Stage To Orbit

- A single-stage-to-orbit vehicle reaches orbit from the surface of a body using only propellants and fluids and without expending tanks, engines, or other major hardware.
- It's somewhat, but not fully "REUSABLE VEHICLE"
- Advantages?
- Disadvantages?



CHALLENGES

- High Orbital Velocity of ~7400 m/sec
- Overcome Earth's gravity
- Limitation of speed in Earth's atmosphere, affecting Engines Efficiency.
- Achieving High enough M-R for carrying sufficient propellants & Meaningful payload weight.
- Weaker gravitational fields as well as Lower pressure than earth atmosphere is favoured for SSTO launch (Think of Moon) [Less fuel utility/ unit time]
- Fuels?

Few Calculations regarding staged rockets:

Recall the eqn, $\boldsymbol{\Delta v = I_{sp} \cdot g_0 \cdot \ln (M_0/M_f)}$

Focus on : M_0/M_f term

$$M_0 = M_{prop} + M_{pay} + M_{rocket}$$

$$M_f = M_{pay} + M_{rocket}$$

Dividing the last two equations,

$$\Delta v = I_{sp} \cdot g_0 \cdot \ln \left[1 + \frac{M_{prop}}{M_{pay} + M_{rocket}} \right]$$

$$\text{Let } \zeta = \text{Propellant mass fraction} = \frac{M_{prop}}{M_{prop} + M_{rocket} + M_{pay}}$$

$$\lambda = \text{Structural coefficient} = \frac{M_{rocket}}{M_{rocket} + M_{pay}}$$

$$M_i = \text{Total Initial Wet Mass} = M_{prop} + M_{rocket} + M_{pay}$$

$$\Rightarrow \frac{M_{rocket}}{M_i} = \lambda\left[1 - \frac{M_{prop}}{M_i}\right]$$

$$\Rightarrow M_i = \frac{M_{prop}}{\left[1 - \frac{\zeta}{(1-\lambda)}\right]}$$

This equation shows how the size of the vehicle and structural coefficient are related for a SSTO Model

- What is the maximum structural coefficient a mission can have?
- Given the specific impulse, required velocity to attain a certain orbit, and fixed payload, how can you relate the rocket's size with structural coefficient (λ)?
- Can the same model be extended to a DSTO rocket?
- If so, what changes need to be made in order to accomplish that?
- Can this theory be applied to a rocket with > 2 stages?

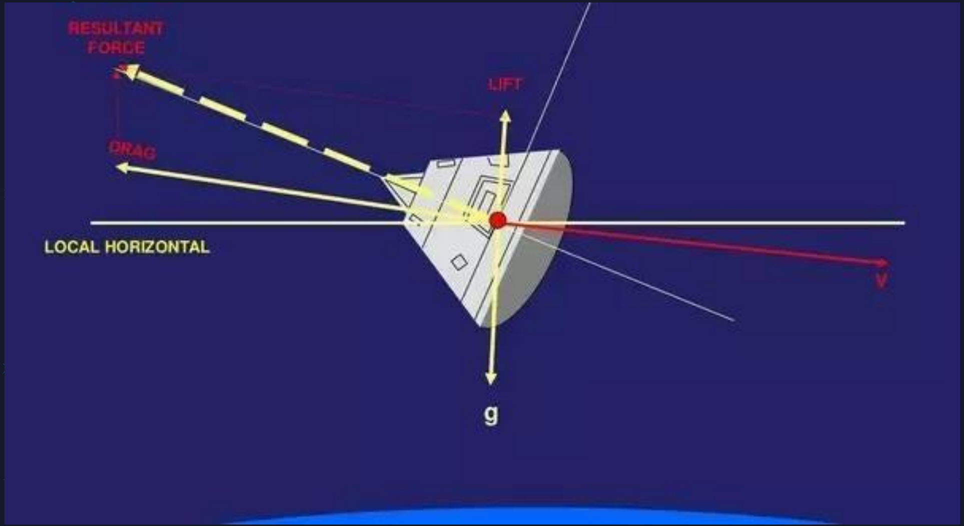
Re-entry

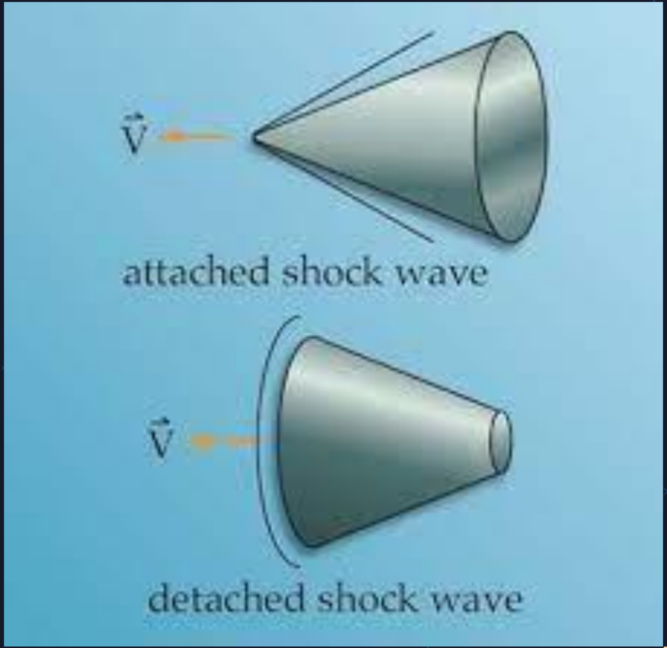
RE-ENTRY MANEUVER

GUIDED

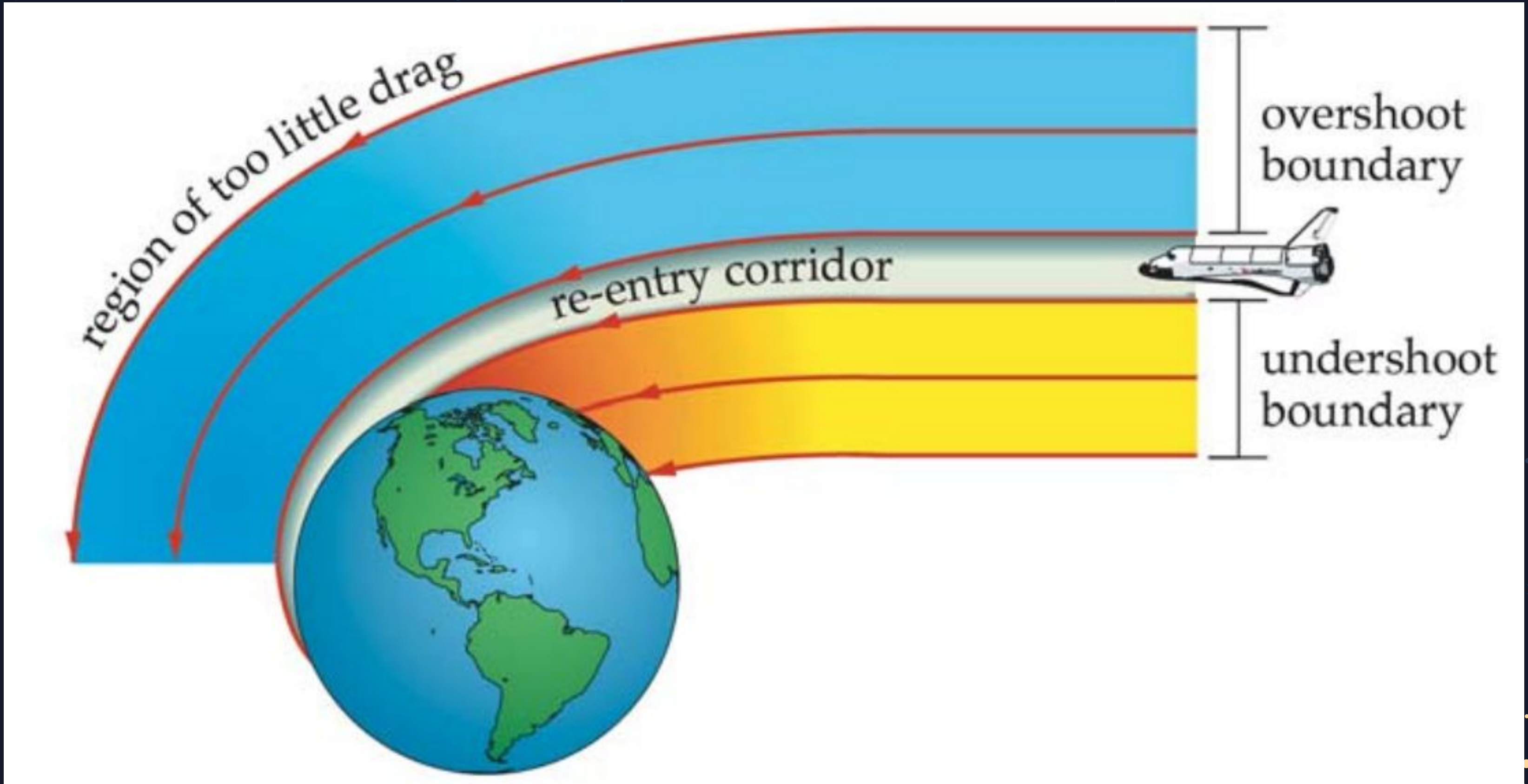
UNGUIDED

LIFT DURING RE-ENTRY

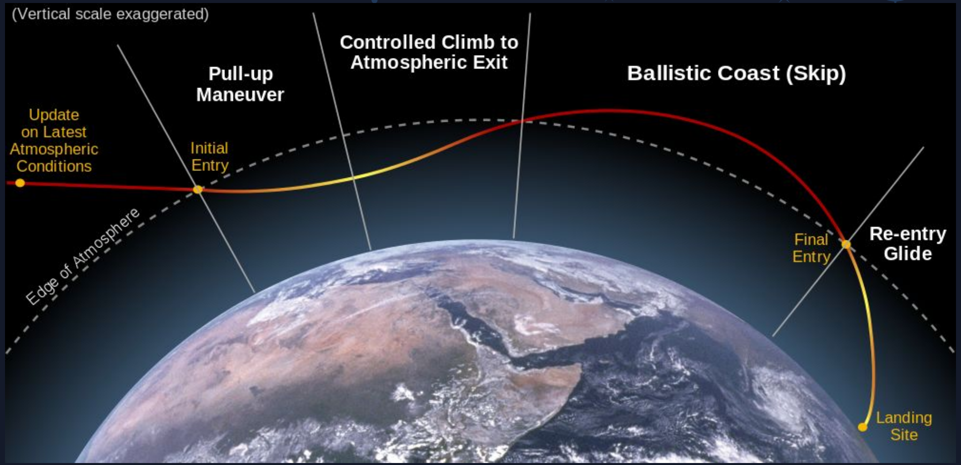


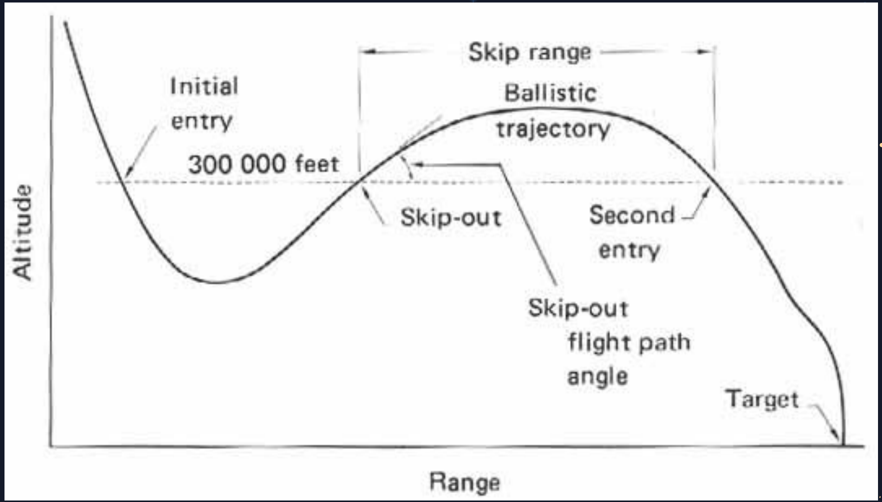


RE-ENTRY CORRIDOR

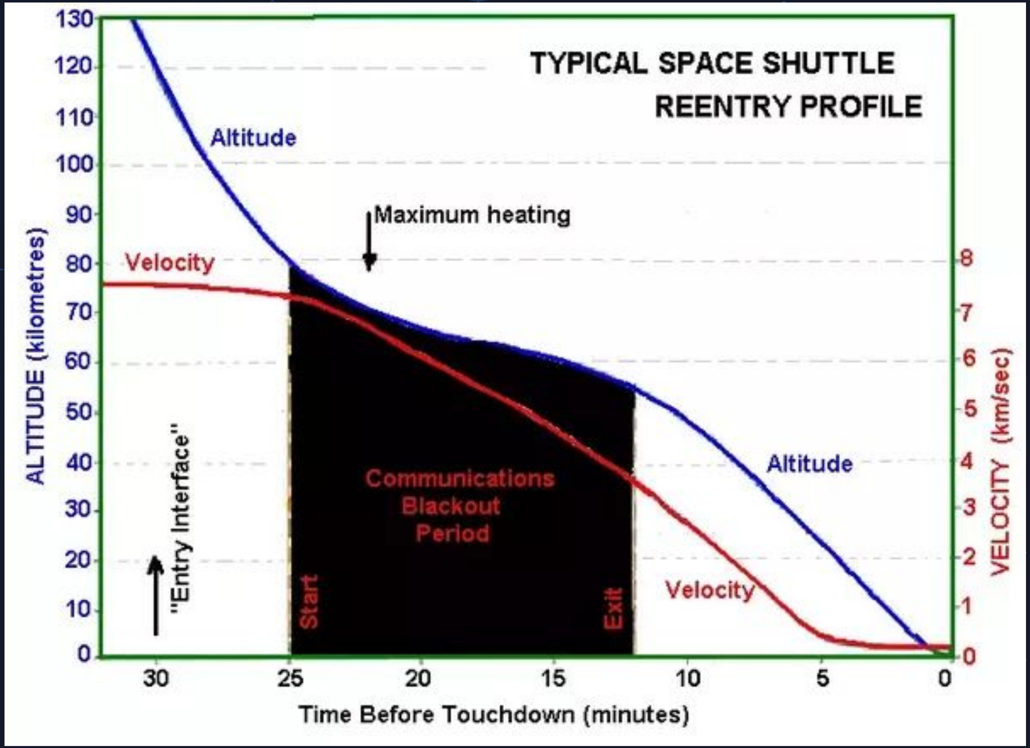


RE-ENTRY MANEUVER





HEATING DURING RE-ENTRY



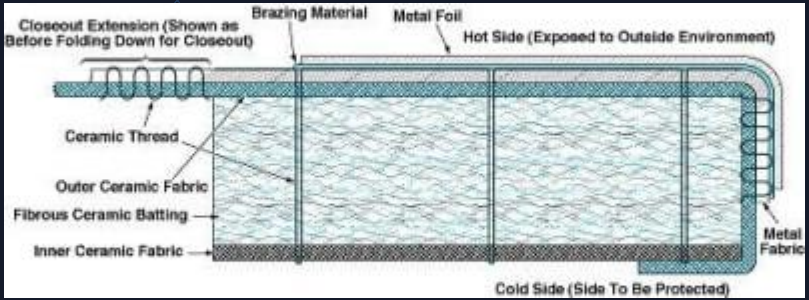
Heat Shields

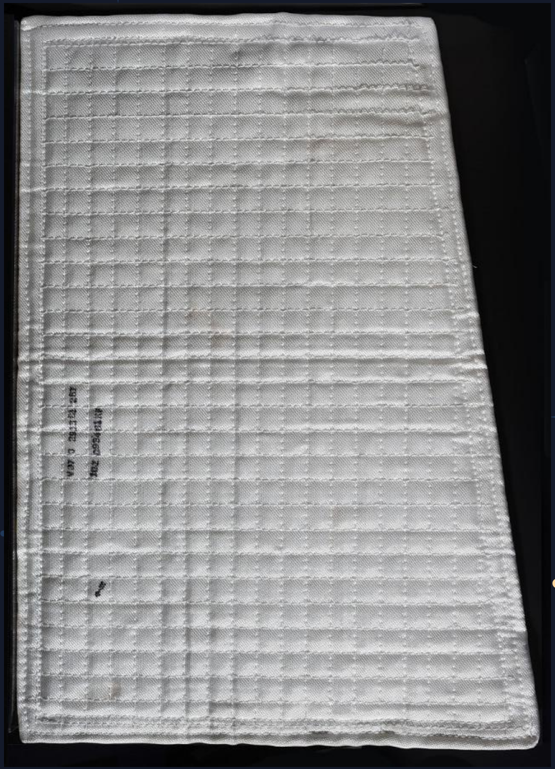
Types of Heat Shields

- Insulation Blankets
- Insulation Tiles
- Reinforced carbon carbon
- Ablative Heat shield
- Regenerative Cooling

Insulation Blankets

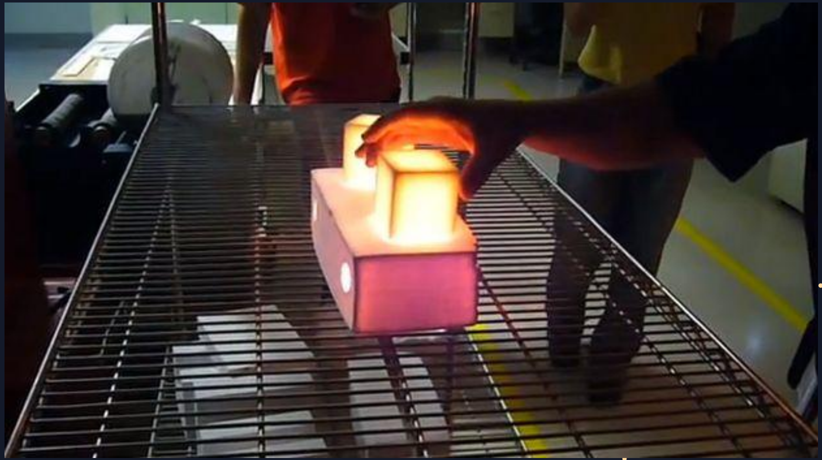
- Used where heat of re-entry < 649 ºC
- Firmly hold on to the spacecraft
- Easier to Maintain
- Looks like a blanket





Insulation Tiles

- Can withstand temp upto 1260ºC
- Made of silica ceramics
- Very bad conductor of electricity
- Extremely fragile
- Possibility of dropping off



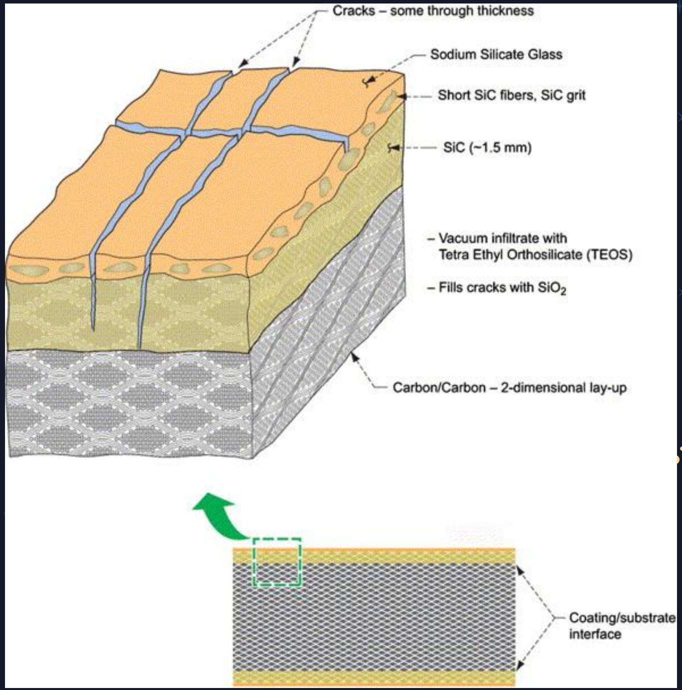
Columbia Shuttle Disaster

Space Shuttle Columbia debris strike (2003)

STS-27 with metal mount under the chip

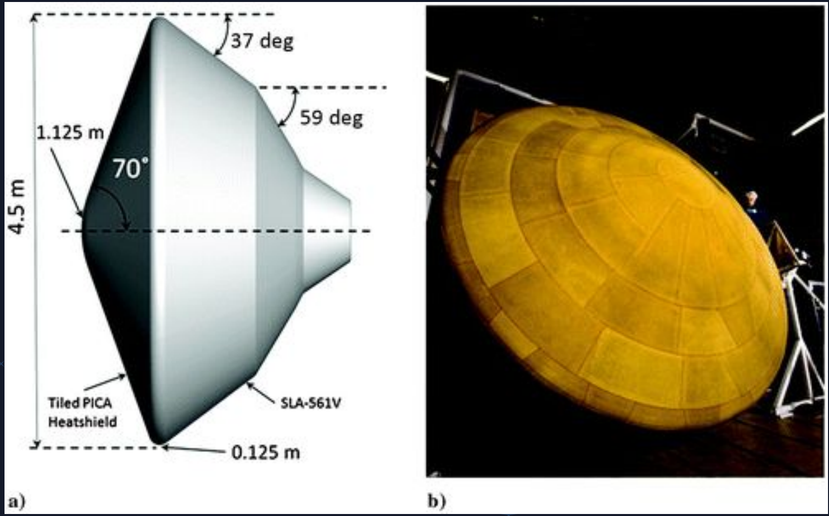
Reinforced carbon carbon

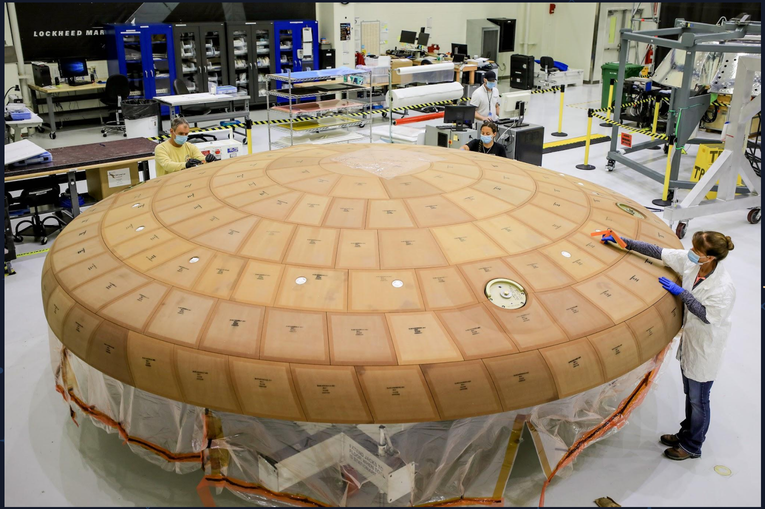
- Carbon fiber reinforcement in matrix of graphite
- Used where temp > 1260ºC
- Heavy but very strong
- Used on leading components, like nose cone and wing edge



Ablative Heat shield

- SLWA (Super Light-Weight Ablator)
- AVCOAT (used in Apollo missions)
- PICA (Phenol Impregnated Carbon Ablator)





Regenerative Cooling

- To be used in more advanced rockets
- Experimental tech
- Uses transpiration to cool off
- Will use cryogenic engine fuel