Heritage Materials for Launch Vehicles and Spacecraft

- The key driving forces in materials development for spaceflight are generally weight reduction, application-specific performance improvements (such as increased temperature capability), and reduced cost.
- Key issues to be addressed by advanced materials development work include material properties (design values) and material fabrication.
- Component performance is primarily determined by mechanical properties (e.g., Ftu, Fty, %elongation, RA, stiffness, damage tolerance) and physical and chemical properties (e.g., density and corrosion resistance across temperatures).
- Suitable fabrication methods play a crucial role in improving material properties, decreasing cost, and minimizing the time between design and hardware build.
- Life cycle costs also influence the economic viability of materials for space use.

This document lists common, heritage materials for spaceflight.

Applications for specific materials are also identified.

Launch Vehicle Structures

- **Pressurized Tanks**

  -2000-series aluminum alloys (2219, 2195)

  -Graphite-epoxy face sheets plus aramid-reinforced phenolic honeycomb core

- **Pressure Vessels** (hydraulic fluid, secondary propulsion or reaction control propellants, helium for system pressurization)

  -Ti-6Al-4V

  -COPVs with Al, CRES, or Ti liners

  -Filament wound composite layers on top of metal liners

- **Unpressurized structures**

  -2000 and 7000-series aluminum alloys

Launch Vehicle Structures

Intertanks, Skirts, Adapters

-2000-series aluminum alloys (2219, 2195)

-Graphite-epoxy sandwich composites

-Beryllium-aluminum

Thermal Protection Systems (TPS)

- Coatings
  - -Primer (Cryogenic Hexavalent Chromium Epoxy Primer)
- Topcoats
  - -ESD-Electrostatic dissipative coating
  - -Moisture barrier coating (AKA Gacoflex/Hypalon)
- Cryoinsulations
  - Polyisocyanurate foams
  - Polyurethane foams
- Adhesives
  - -Hysol EA 9394
  - -Hysol 608
  - -PPG PR-1664-D
  - -3M 2216
  - -TIGA 321
  - -TIGA 3216

Launch Vehicle Structures

Fairings

-Fiberglass

-Graphite-epoxy face sheets with aluminum honeycomb or foam core

-Forward end of fairing made of aluminum alloy stringers with cork insulation

Launch Vehicle Structures

Material needs

-Weight reduction and increased strength to weight ratio

-Improved weldability

-Improved damage tolerance

-Thermal protection systems: reduced thermal conductivity, resistance to cracking, improved adhesives/bonding agents, improved impact resistance, weight reduction

-non-permeable composites for cryogenic tanks and vacuum operations

-hydrophobic and frictionless coatings; coatings with variable optical properties

-hybrid composite and metal structural materials

-less brittle composite material systems

Engines

Turbomachinery and Combustion Devices

Alloy 718 (60% by weight)
Alloy 625
Alloy 903
JBK75 (cast A286 material)
300 series for high pressure lines
A286 for brazed nozzles
IN100
Titanium 5AL-2.5Sn ELI
Titanium 6AL-6-2
NARloy-Z
Tens 50 aluminum
PWA-1493 single crystal turbine blades
K-Monel

Engines

Lines and Ducts

-321 CRES

-347 CRES

-Alloy 718

-A286

-Hastelloy

Engines

Nozzles (tubular, channel wall, sandwich wall, solid piece, ablative)

Aluminum alloys

Low-alloy steel

Stainless steel

Pure Nickel

Nickel-base alloys

Cobalt base alloys

Titanium alloys

Copper alloys

Niobium alloys

Carbon-carbon

Ceramic Matrix Composites

Silica cloth phenolic

Glass-phenolic

Beryllium

Refractory metals

Carbon cloth phenolic

Engines

Material needs

-Increased thermal conductivity
-Improved strength to weight ratio
-Improved thermal resistance to enable higher operational temperatures
-Improved fatigue life
-Reduction in thermal conductivity mismatch between liners and structural components
-Better resistance to hydrogen embrittlement
-Oxygen flammability resistance
-Additive manufacturing with new materials (refractory, higher temperature)
-Testing and characterization techniques for additively manufactured materaisl
-Methods to determine material properties (design values) for additively manufactured materials

Solid Rocket Boosters

Case Materials

-D6AC

-4130

-18% Nickel Maraging Steel

-Titanium

-2024 aluminum

-Filament-wound reinforced plastics

-Kevlar

-Aramid

-Carbon fiber or graphite fiber

Solid Rocket Boosters

- **Nozzles**
  - -aluminum alloys, Steel alloys

- **Wall materials, ablators, and insulators**
  - -Carbon phenolic, silica phenolic tape, carbon phenolic tape
  - -molded graphite, pyrolytic graphite, carbon or Kevlar cloth with phenolic or plastic resins
  - -Sprayable MCC-1 (Marshall Convergent Coating)
  - -Bond-on Cork
  - -RT-455
  - -Carbon Cloth Phenolic
  - -Rubbers with fillers (common fillers include Kevlar, PBI)
  - -Phenolic resin
  - -Rubber (EPDM) at joints

Solid Rocket Boosters

Material needs

-Higher temperature, lightweight materials

-Green/nontoxic materials to address materials obsolescence issues

-Composite material development for motor casing applications

-Thermally insulating & electrically conductive materials

Spacecraft Structural Materials

-Aluminum alloys (6061-T6, 6061-T651, 7075, 5052-H32)

-Graphite-fiber/polymer matrix composite materials

-Aluminum-lithium alloys

-Beryllium-aluminum alloys

-Boron-aluminum alloys

-Carbon-carbon Composite nozzles

-Silicon phenolic nozzle throats

-Titanium cases and domes

-COPV with aluminum liner

Spacecraft Structural Materials

Lightweight support structures (applications include booms and trusses)

-Carbon fiber composite

-Kevlar

-Glass laminates

-Fiberglass

-Hybrid glass/carbon

Spacecraft Structural Materials

Material needs

-radiation protection

-resistance to atomic oxygen (AO) for low-earth orbit applications

-increased impact resistance to micrometeroid orbit debris (MMOD)

-self-healing materials

-testing and characterization of emissivity and absorbtivity of materials over a wide temperature range representative of thermal swings

-flexible materials

-processing and extraction of *in situ* materials