Hybrid Propellant Selection

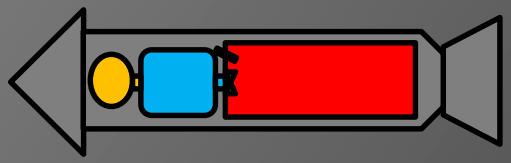
2/13/15

WASHINGTON STATE UNIVERSITY

Recap

- Advantages/Disadvantages
- Oxidizer
- Combustion ports
- Fuel mixture

Design Pr



SCHEMATIC

TESTING & COMPARISON

O FUEL

Layout Selection

- Regular v.s. Inverse
- Oxidizer Pressurization System
  - Dependant upon Oxidizer
- Pre/Post Combustion Chamber

Reverse Hybrids

- Liquid Fuel and Solid Oxidizer
- Downfalls
  - Negates all benefits of Hybrid Rockets
  - Solid Oxidizers are brittle and crack under high heat conditions
  - Solid Oxidizers used in rocketry are usually explosive
  - Liquid fuels must be handled with care.
- Upsides
  - None

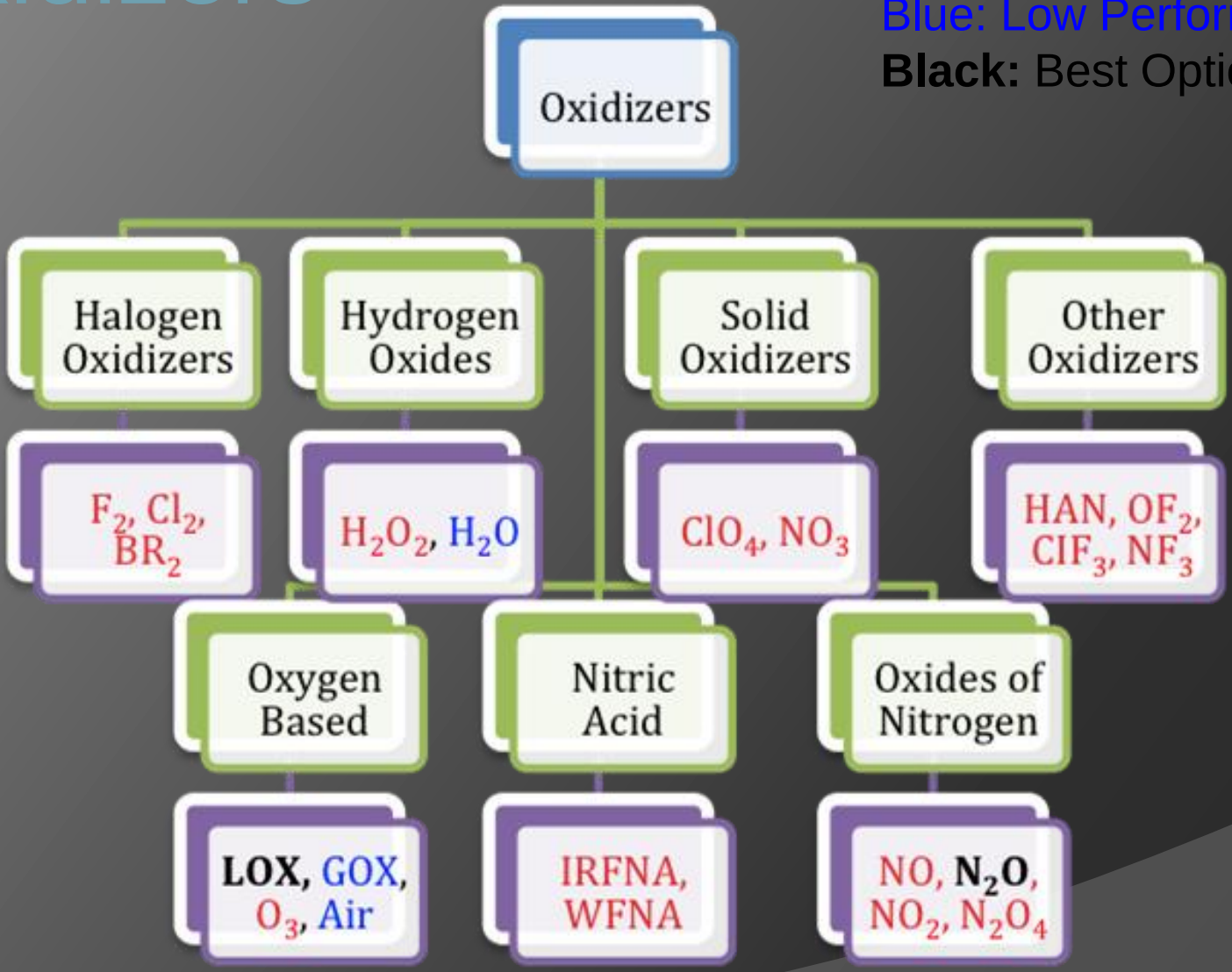
Oxidizers

Oxidizer Selection Process

- What works well with fuel
- Specific Impulse
- Density
- Stability/Equipment Needed
- Availability/Price

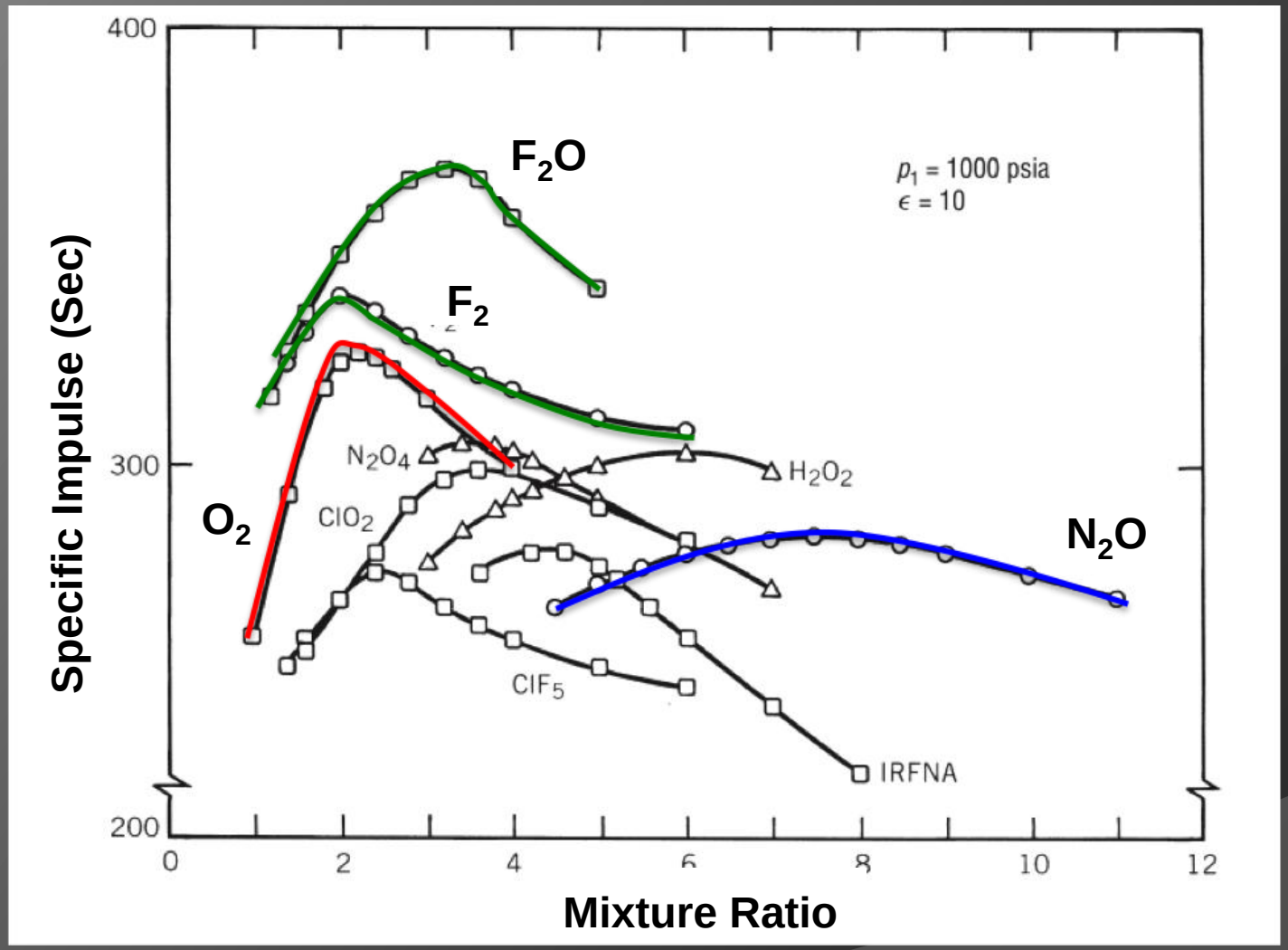
Oxidizers

Red: Toxic or Sensitive
Blue: Low Performance
Black: Best Options



https://aa.stanford.edu/events/50thAnniversary/media/Karabeyoglu.pdf (Slide 21)

Oxidizers



Sutton, George P., and Oscar Biblarz. *Rocket Propulsion Elements*. Hoboken, NJ: Wiley, 2010. Print.

Oxidizers

Fluorine (F_2O/F_2)

- Why we looked at it:
  - Highest Specific Impulse
  - Light Weight
- Why we won't use it:
  - Unstable
  - Corrosive
  - Highly Toxic
  - Expensive & Rare
  - BANNED

St. Peterburg's Museum of Space Flight: RD-301 - an exotic rocket engine powered by liquid fluorine and ammonia that would have been used as on the Proton rocket as an upper stage, before realities of using fluorine kicks in

Oxidizers

Liquid Oxygen (LOX)

- Why we looked at it:
  - High Specific Impulse
  - Readily Available
  - 2nd Most Common Oxidizer in other hybrid rockets
- Why we won't use it:
  - Expensive
  - Not Self Pressurizing
  - Cryogenic

Oxidizers

Nitrous Oxide (N_2O)

- Density: 1.22 g/mL
- Melting Point: -90.8 C
- Boiling Point: -88.5 C

- Advantages
  - Most Common Oxidizer in Hybrid Rockets
  - Self Pressurizing
  - Positive heat of formation
  - Readily Available
- Disadvantages
  - Varying Boil off Pressure
  - Susceptible to Deflagration/Detonation

$$N_2O \rightarrow N_2 + \frac{1}{2}O_2 + 19.61\,\frac{kcal}{mole}$$

Solid Fuels

What Can We Use...

ANYTHING!

Solid Fuel Selection Process

- Research Common Fuels
  - Metrics
    - Regression Rate
    - Density
    - Specific Impulse
    - Stability
    - Availability/Cost

However, the process was not as straight forward as oxidizer selection...

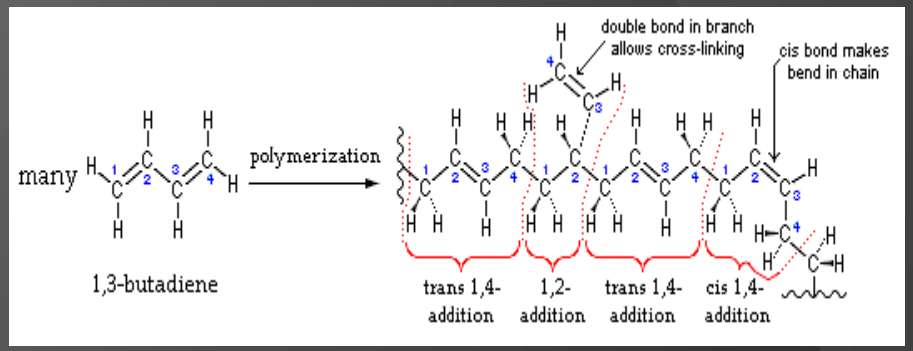
Things we considered...

...and immediately threw out

- Cryogenic
  - MMH (Monomethyl Hydrazine)
  - UDMH (Unsymmetrical dimethyl hydrazine) - Toxic
  - Aerozine 50
- PVC - Produces Toxic Chlorine Gas

Solid Fuels

- HTPB - (R45-M)
  - Density - 0.9494 g/ml
  - Mixed with catalysts and curing agents to polymerize
- Hardener (SUL-4 Resin)
  - lengthen mer chains to make HTPB stiffer, stronger, and harder.
  - Catalyst (Isonate 143-L)
    - Start polymerization process
  - Final Density
    - 0.9651 g/ml



http://en.wikipedia.org/wiki/Hydroxyl-terminated_polybutadiene

- Advantages
  - Inexpensive
  - Chemically stable
  - Readily available
  - Most Common Hybrid Solid Fuel
- Disadvantages
  - Low Regression Rate
  - Complex Curing Ratios

Solid Fuels

- Paraffin Wax
  - Density ~ 900 kg/m^3
  - Melting Point ~ 50 & 70 C
  - Boiling point > 370 C

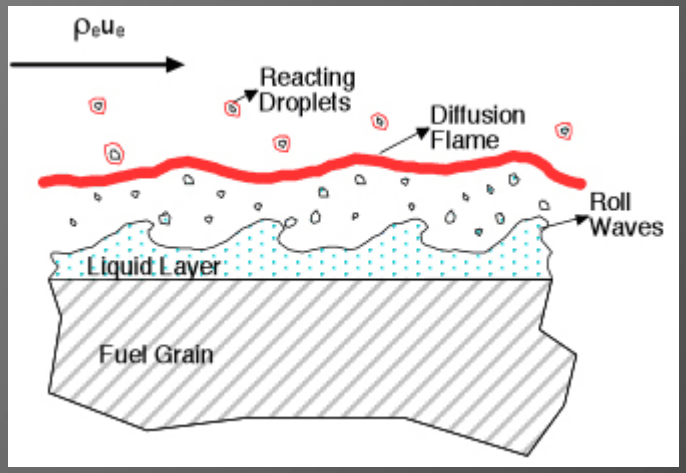


Diagram of Liquid Combustion Theory
Courtesy of Space Propulsion Group
http://www.spg-corp.com/advanced-hybrid-rocket-fuels.html

- Advantages
  - High Regression Rate
    - Sea Wave Effect
  - High Specific Impulse
- Disadvantages
  - Properties can vary drastically
  - Unstable and Soft
  - Premature Melting

Solid Fuels

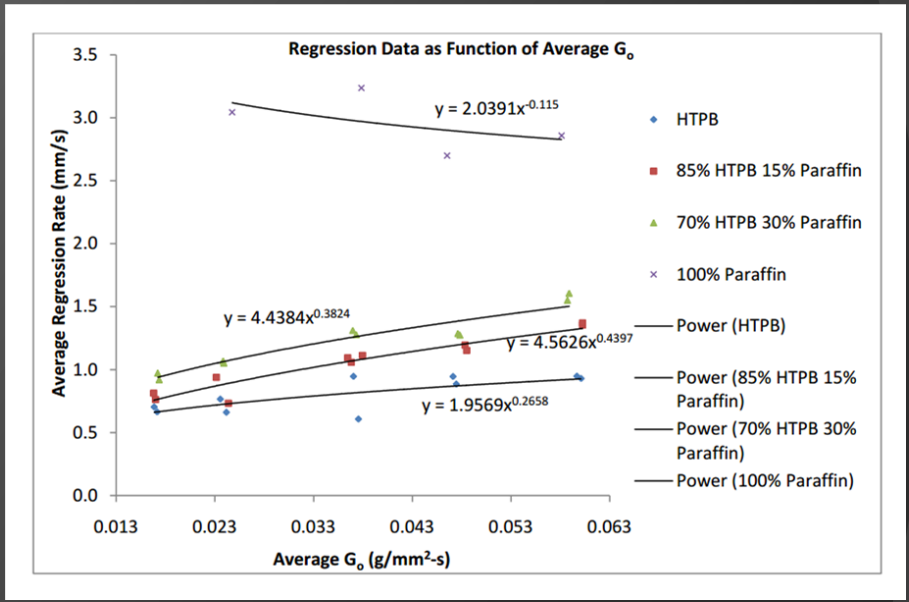
- Nylon (Thermoplastic Polyamide)
  - SpaceShip Two Motor = N2O/Nylon Motor
- Currently no casting information available

http://www.gizmag.com/spaceship2-virgin-galactic-supersonic-record-branson/30418/

Non-Homogeneous Solids

- Problems with
  - Solid HTPB
    - Low Regression Rate
  - Solid Paraffin
    - Prone to breakage
    - Low Density
- Solution: Non-homogeneous Fuel
  - Increases Regression Rate compared to HTPB
  - Increases Stability Compared to Paraffin
  - Turbulent Surface increases regression

Different Compositions Produce Different Results



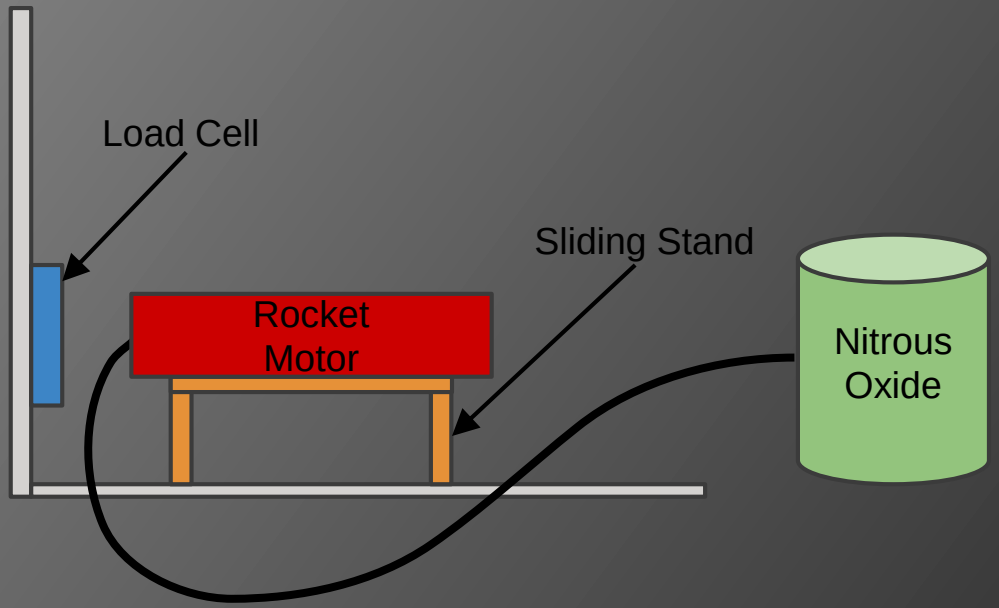
Non-homogeneous Hybrid Rocket Fuel for Enhanced Regression Rates Utilizing Partial Entrainement by Kenny Boronowsky

Additives to Solid Fuels

- Carbon Black
  - Prevents Premature Melting
- Metals (increase performance)
  - Aluminum
    - Increase Heat Transfer by adding radiation
  - Lithium
    - Lowers heat of combustion

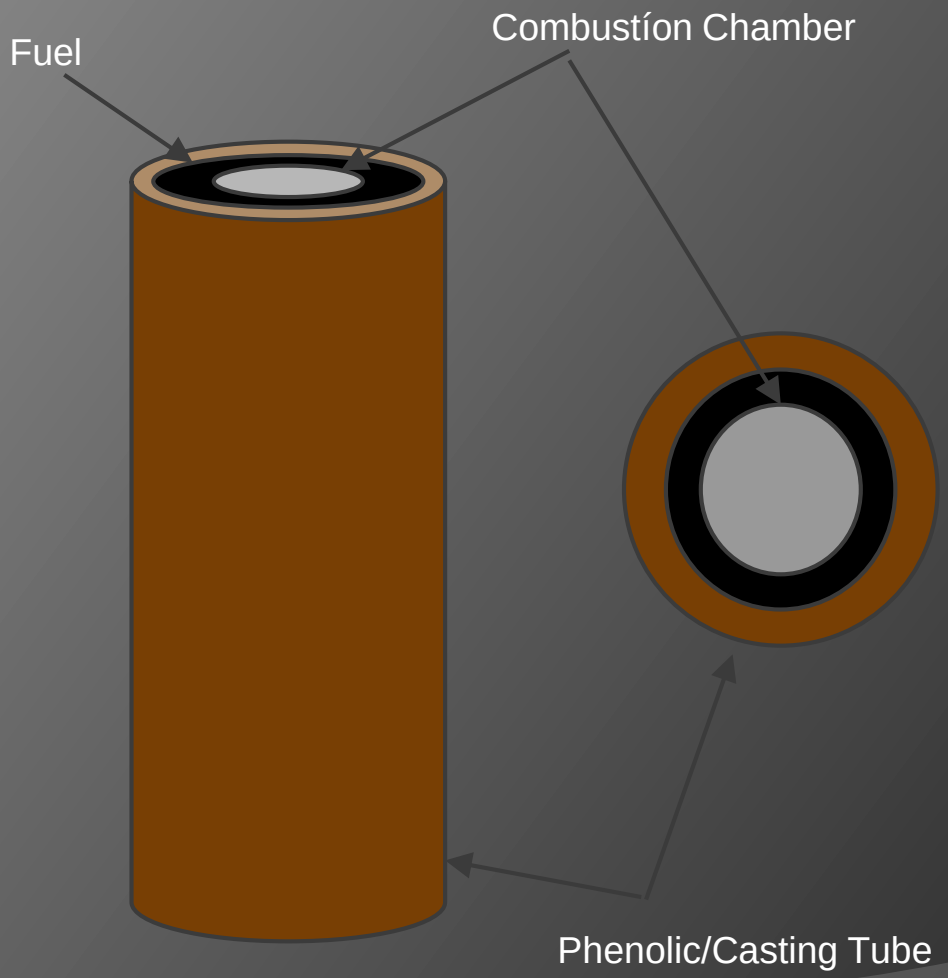
TESTING & COMPARISON

Testing Procedures



- Cast Propellants
- Build Test Stand
- Build Motor Housing
- Measure Thrust and Regression Rate

Casting Our Own Propellant



- Cast Propellants
  - Place Tube in Casting Hole
  - Mix Chemicals
  - Pour into Tube
  - Place Mandrel through Center
  - Cure
  - Possible Degassing

Our Selection

- Fluid Oxidizers
  - Nitrous Oxide
- Solid Fuels
  - HTPB Solid
  - Paraffin
  - HTPB/Paraffin Mix
  - Nylon
- Additives
  - Aluminum
  - Carbon Black

Questions

WASHINGTON STATE UNIVERSITY