

# Design to Cost

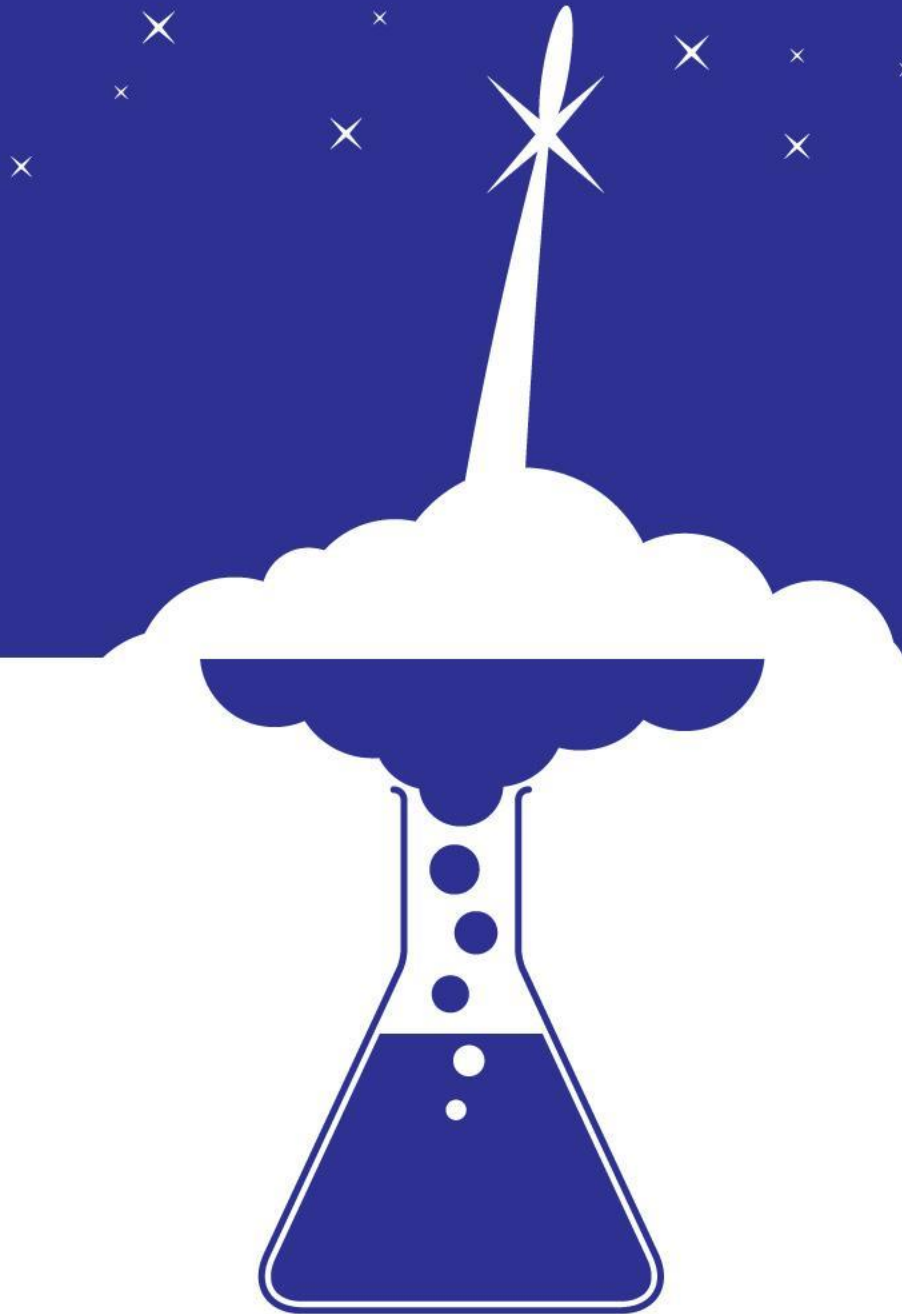
By Mark Ventura

1/23/2023

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Huntington Beach, CA, VESM109-001

ACADEMIC-INDUSTRY  
LIQUID ROCKET SYMPOSIUM **2023**



# Mark Ventura CV

- BSME University of Pennsylvania
- MSE Purdue University, Rocket Propulsion
- Licensed California Professional Engineer
- World Expert Hydrogen Peroxide Propulsion
- Space Shuttle, X-34, UARS, Space Station, EELV, Mars Lander, Comsat, ABL, THEL, VG, VO, O&G, Cryport, New Space, solar, lots I can't talk about

- **Cost**
- 10 years conventional aerospace
  - Rockwell International, X-34 Stage 1 Propulsion Manager ~ \$30M in ~ '94
- 25 years entrepreneurial
- Routinely compete FFP with large and small companies
- Large, small, conventional and unconventional business
- Mature and VC

- **COPV**
- Space Shuttle Main Propulsion Helium Sub-System Expert
- Helium tank thermo-fluid dynamic modeling simulation
- Helium tank transient thermodynamic modeling and simulation
- Design change from Kevlar/Titanium to GrEp/SS
- New Space pressurant tanks
- Chilled helium fast fill

- **Cryogenics**
- LO2, LH2, LN2, LNG, CH4, Neon, N2O\*, CO2\*
- Space Shuttle Main Propulsion
- Space Shuttle cryo payloads
- Space Station cryo supercritical tanks
- High energy density cryo mixed fuel/oxidizer blends
- Cryoport start-up
- Dry Ice makers, biotech
- New Space tank testing

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# Factors that Create Cost Issues

- Fundamental design decisions that incur larger than necessary cost
- Inefficient use of labor
  
- Solving technical problems with cost that have other lower or no-cost solutions
- Copying expensive practices
- Programmatic features that conflict with academic scale constraints

## Expensive

Industry best practices

Herd operations

Buy parts

COTS solenoid

valves

Battleship test stands



## Lower Cost

KISS

Industrial eng.

Repair parts

Custom valves

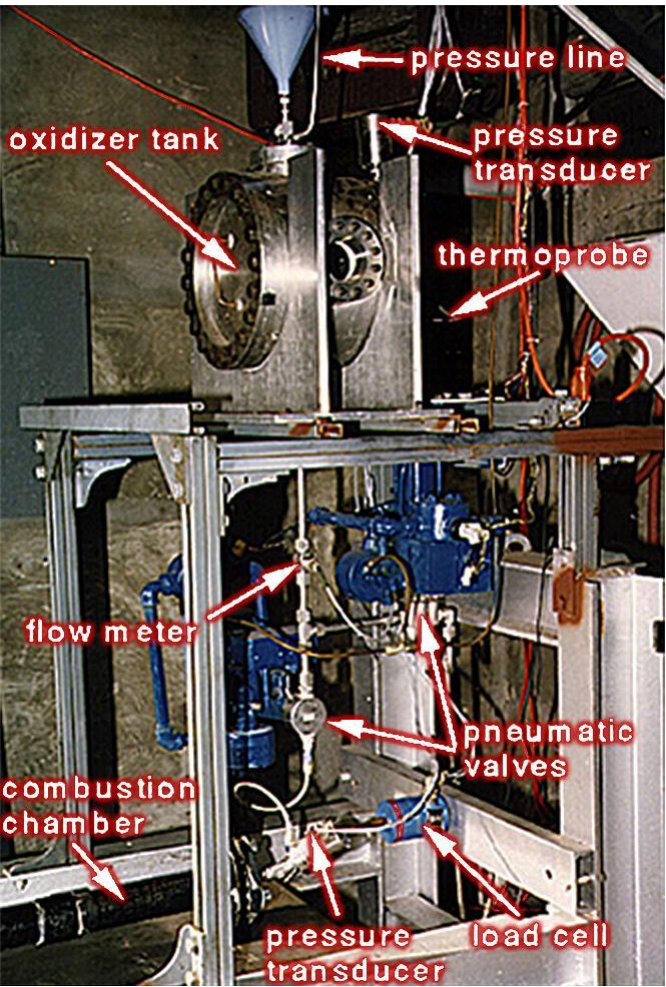
2-person max lift



# Can I Buy Everything at Target?

# Two Examples

Ventura MS 85% H2O2 Hybrid



- Scrap combustion bomb
- Trash Unistrut
- Scrap I-beam, wind tunnel
- Trash irrigation pipe
- Odds and end fittings, eclectic
- Unused valves, Purdue
- Borrowed P-ducers
- Scrap TC wire
- Ice water TC junction

- Purchased parts
- 2 Teflon o-rings for tank
- Propellant
- Passivation chemicals
- Minor pipe fittings
- School OPEX – GN2
- School CAPEX – Lab equip
- Donation – Welder
- 5 heads, 1 semester

Ventura RRS 85% H2O2 Hybrid

- Blowdown pressurization
- Fill valve – pipe plug
- PVC structure
- Solvent welded joints
- “No machined parts”
- Simple graphite nozzle
- Simple pyro valve

- Catalytic ignition
- All materials fit inside small car
- Hand tools, drill press
- Commercial injector
- One moving part
- Duct tape
- Hose clamp
- C-clamps
- Unistrut



# Complexity Drives Cost

- If it does not exist it:
  - Has no material cost
  - Has no integration cost
  - Has no non-recurring/engineering cost
  - Cannot break
  - Has zero mass
- Every feature, component, and function adds cost
- Learn creativity in reducing complexity

# Amateur or Professional

- |                   |                 |
|-------------------|-----------------|
| • Complex         | Simple          |
| • Regulated       | Blowdown        |
| • Flight controls | Nothing         |
| • Crane ops       | Manual lift     |
| • Cryogenic       | Storable        |
| • Haz gas         | None            |
| • Assy req'd      | Pre-assembled   |
| • Pyrotechnics    | None            |
| • Flight data     | None or limited |

Simple Looks Like a Hobby Solid – Use that as a goal

Design goal is Hobby Solid NRE, Rec, and Ops cost

# Labor is a Finite Cost

- Labor is often very poorly utilized
- Large numbers of lookey-loos
- Labor is actually a finite resource, your team can only work so many hours per quarter/semester
  
- Getting people to work effectively is **WORK** (aka management)
  - Telling people to do something is not very effective
  - Training and showing people what to do is leadership
- Simplify program goals to fit what is doable

# #1 Squandered Asset



14 persons  
Maybe 1-2 working

## Tools and Tips

- Track labor costs, use a time clock and WBS
- LEARN by reconstructing actuals and compare
- Detailed tasks statements, not make it happen

# Expensive Copycat Examples

- COTS cryogenic solenoid valves
- Pressure regulated pressurization
- Helium
- Trick custom propellant valves
- Trailer test skid
  
- Heavy weight run tanks
- Swage-lok style fittings
- COPV
- Buy everything, focus on cash as a program management tool

# Lower Cost Solutions

- Fix surplus regulator vs buy \$1000 regulator
- Swagelok vs 37 degree flare fittings
- Large tanks vs “to size” or undersize tanks
  - Weight
  - Handling
  - Lifting and rigging
  - Pressurant gas
  - Higher cost fittings
  
- On-campus “junk”, find a scrounger
- Hoard materials
- Make friends, network, trade with other groups
- Scrap materials

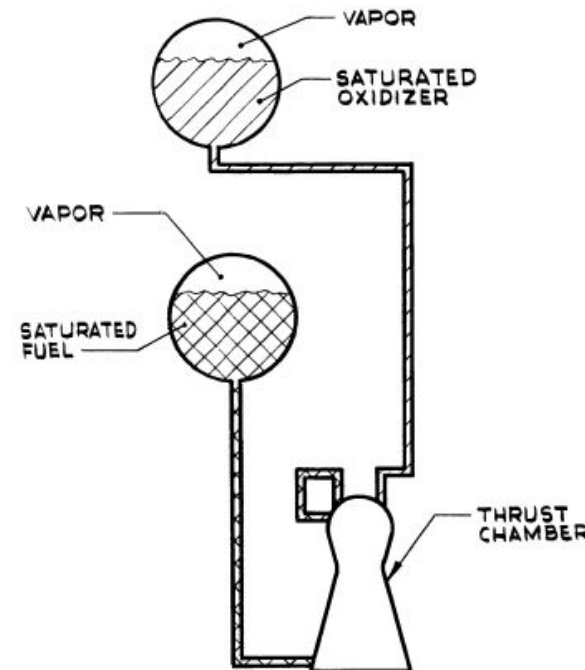
# Programmatic Cost Drivers

- Large Heavy “Mobile” Test Stand
  - Doubles materials, labor, NRE, fixes recurring costs
  - More opex: Labor, crane, forklift, trailer, truck, rigging
  - Doubles validation for flight system

- Pressure regulated
  - Eliminates pressurant tank, high pressure ops, F/D vlvs, relief/burst, fittings regulator(s), filters, bracketry and development

- Cryogenics
  - No time constraints
  - Parts easier to source, Less GSE
  - Less hazards and failure modes

# 80/20 Concept



Vapak Pressurization

NASA/GSFC, Study of Pressurization Systems for Liquid Propulsion Rocket Engine, Report 2335, 9/15/1962



# Questions

- What are the metrics of Earned Value and what do they mean? How are they used?
- What is the legal difference between Exempt and Non-Exempt employees?
- Can you name an engineering organization that uses collective bargaining?
- Is additive manufacturing lower cost than subtractive manufacturing?
- What is the average labor rate for an aerospace engineer in Southern California and Huntsville, Alabama?
- Investment casting is over 5000 years old. Where is it used? What are the benefits? Is AM better?
- What are the Taguchi Method and the Design of Experiments?
- How much did my rocket engine test cost using:
  - Minimum wage
  - Low end fully wrapped labor rates
  - Typical industry labor rates?

# Keep It Simple Stupid (KISS)

- Simple systems are harder to design
- Engineers tend towards complex
- Good RRS examples: Wherley, Claflin, McKinnon
  - ~ 1 person teams, ~ 2 years to design build, static fire and fly 1000 lbf LO2/fuel bi-props
  - Static fired flight hardware
- One (1) person can ship device in a sedan car
- Set-up and deploy in 2 days (~ 20 to 30 hrs)
- Limits Ground Support Equipment
- De facto limits Labor cost



“If it doesn’t work, we’ll drink the fuel.”

Wherley LO2/alcohol rocket

Analog gauge

D2 tank

Surplus piece parts

Flight weight static fire

Copper lines field fab

# Who Cares?

- 1 test per quarter/semester/year
- Typical Field Deployment ~ 800 hrs
- Typical Quarter/Semester ~ 4000 hrs (2 person years)
- Typical cash budget \$10,000
  
- Value ~ 1-2 test per year
  
- Cost for 1-2 test per year
- Minimum wage \$72,000
- Lowest likely industry labor value \$210,000
- Likely industry cost > \$400,000

**What happens to the value if you  
double the number of tests?**