

# Barriers to Low Cost Space


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**What determines  
What humanity  
can accomplish  
In space?**

**Risk**

**Vision**

**Technology**

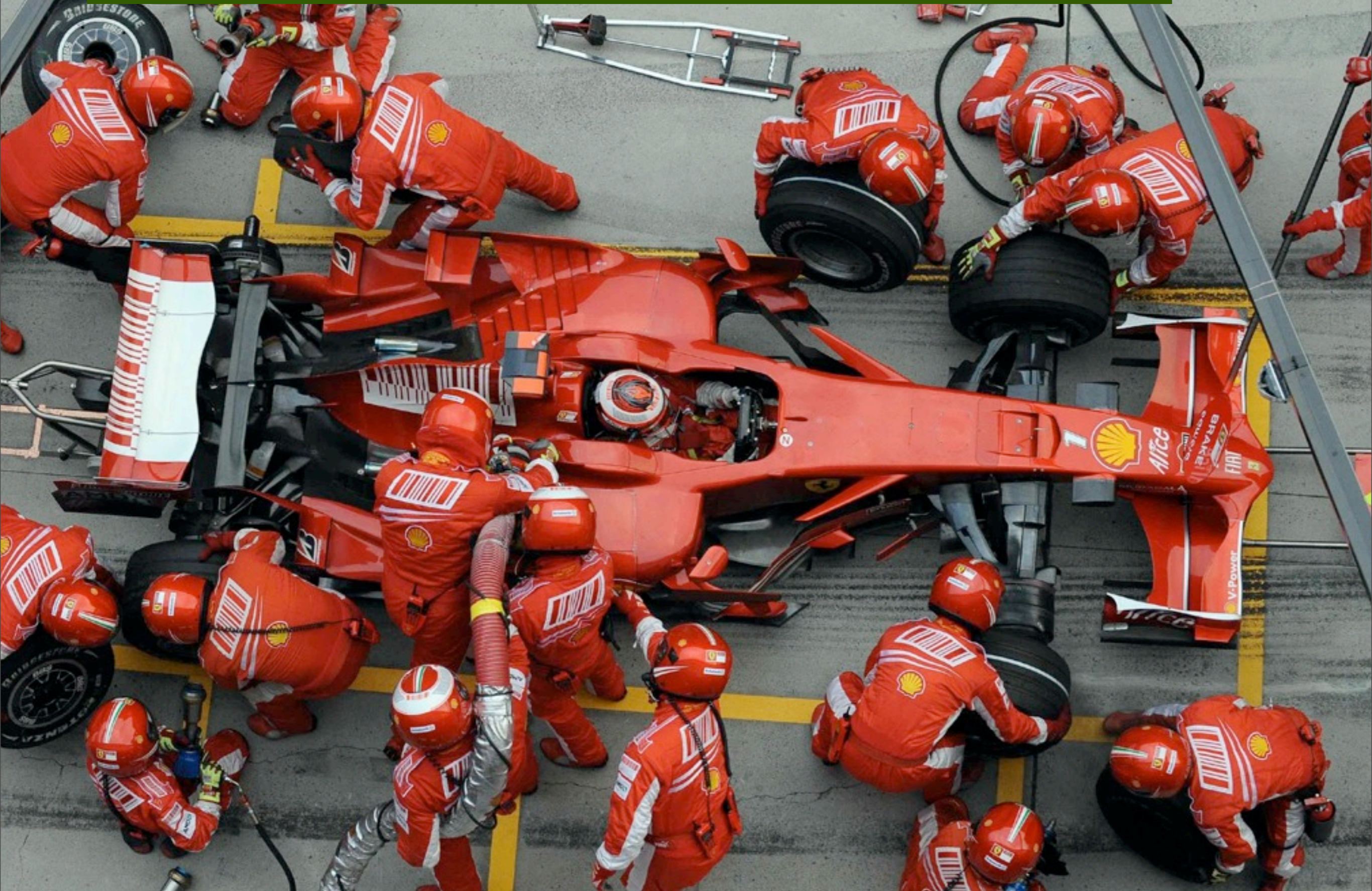
**Transportation**

**Management**

**Where do we want to go today?**



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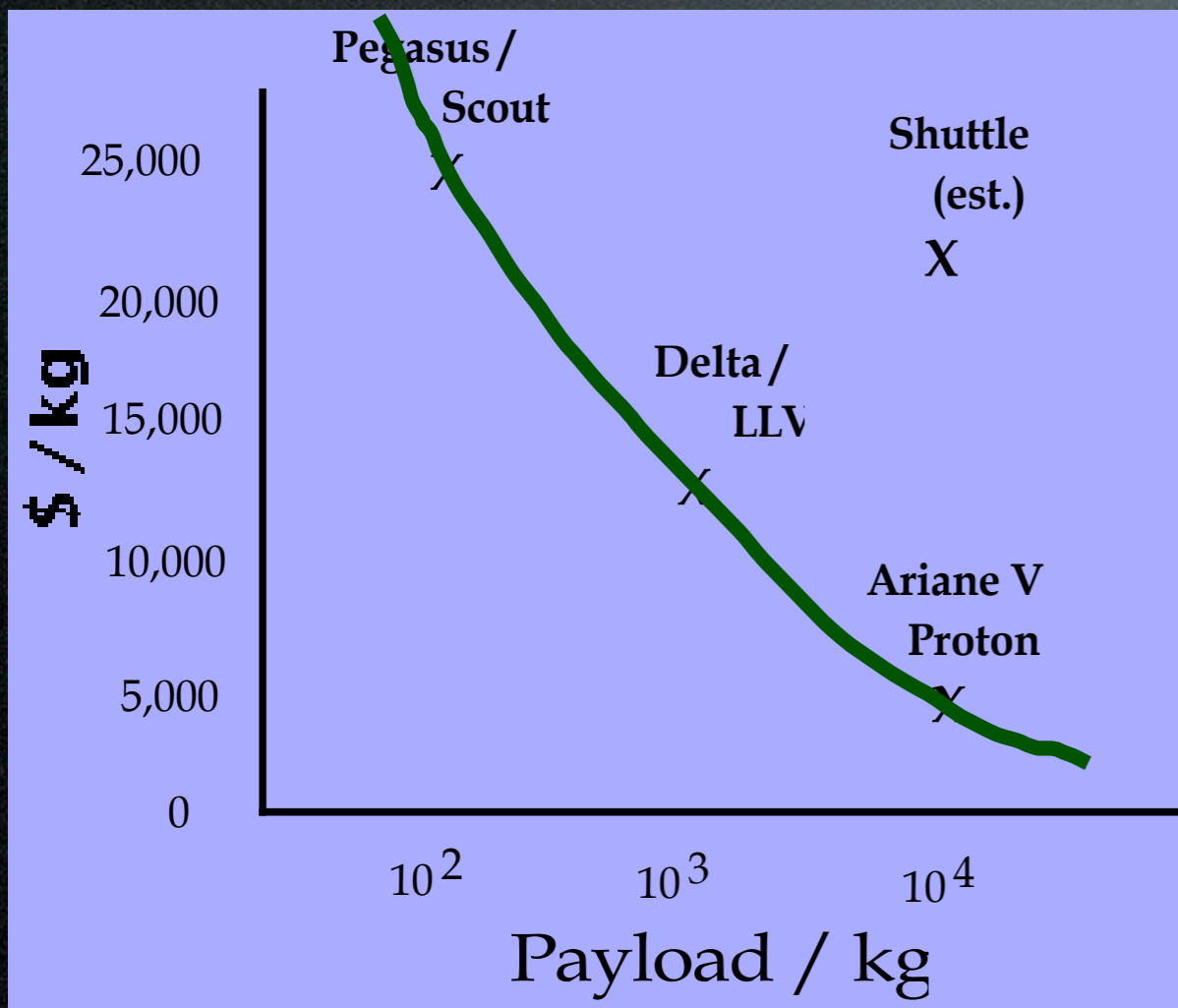
# Topics I

- Mission Mindset (where do you want to go today)
- Transportation (expensive, stressful, to the wrong place, meetings, "safety" requirements: inhibits, structure, discharged) small envelopes, long wait, limited access, far away, meetings, delays, ITAR)
- requirements: rigid, long life single items vs. continuous evolving systems of multiple elements
- management structure
- non-productive uses of engineering team
  - reviews - documentation
  - oversight (quality, parts)
  - management: meetings, doing non-engineering
  - trading off and analyzing versus doing
  - most other stuff done with a computer
- No infrastructure: in orbit, spectrum, R&D to solve recurring problems, shopping, guidelines and prefab (ie it's all custom custom custom)

# The last 1(00) mile(s)

- Naïve Observations:

- Bigger rockets are cheaper, regardless of who builds them
- '50s technology Scout costs LESS than '90s technology Pegasus
- Bringing things back from orbit and/or crewed vehicles:  
-> costs more
- Marginal cost to fly a 10 kg payload: 50k€.



# SIZE MATTERS



Passenger = 100 kg  
Launch = 1000 miles



# How Transportation Designs Society

## Jet Travel: assume R/T ticket costs \$100,000

- Would airlines exist? ATC? FedEx?
- Would Akron, Exeter, Van Nuys, Bristol, Bergamo... have airports?
- Who would have access to air travel? For what “missions”?
- How would society determine what needs justify use of resource
- Would you have taken your last...
  - vacation
  - business trip
- Where would you / your kids go to college?
- Would you take a job 500, 1000, 1500 miles from family?
- Collaboration across US / Europe possible? ESA? NASA? ISS?

## Road Trip: assume gas \$500/gal // 100€/litre, car costs €1M

- Would production lines exist?
- Autostrade? Gas stations? Provincial roads?
- Who would operate bus / train systems and determine where they offer service?
- Suburbia, Single Family Homes? Baltimore / Washington complex? Northeast Corridor? Florida?
- Could US be governed from DC? Who has access to leaders?
- Progress in Medicine? Technology? Trade?

# How Transportation Designs the Satellite

## Engineering Design

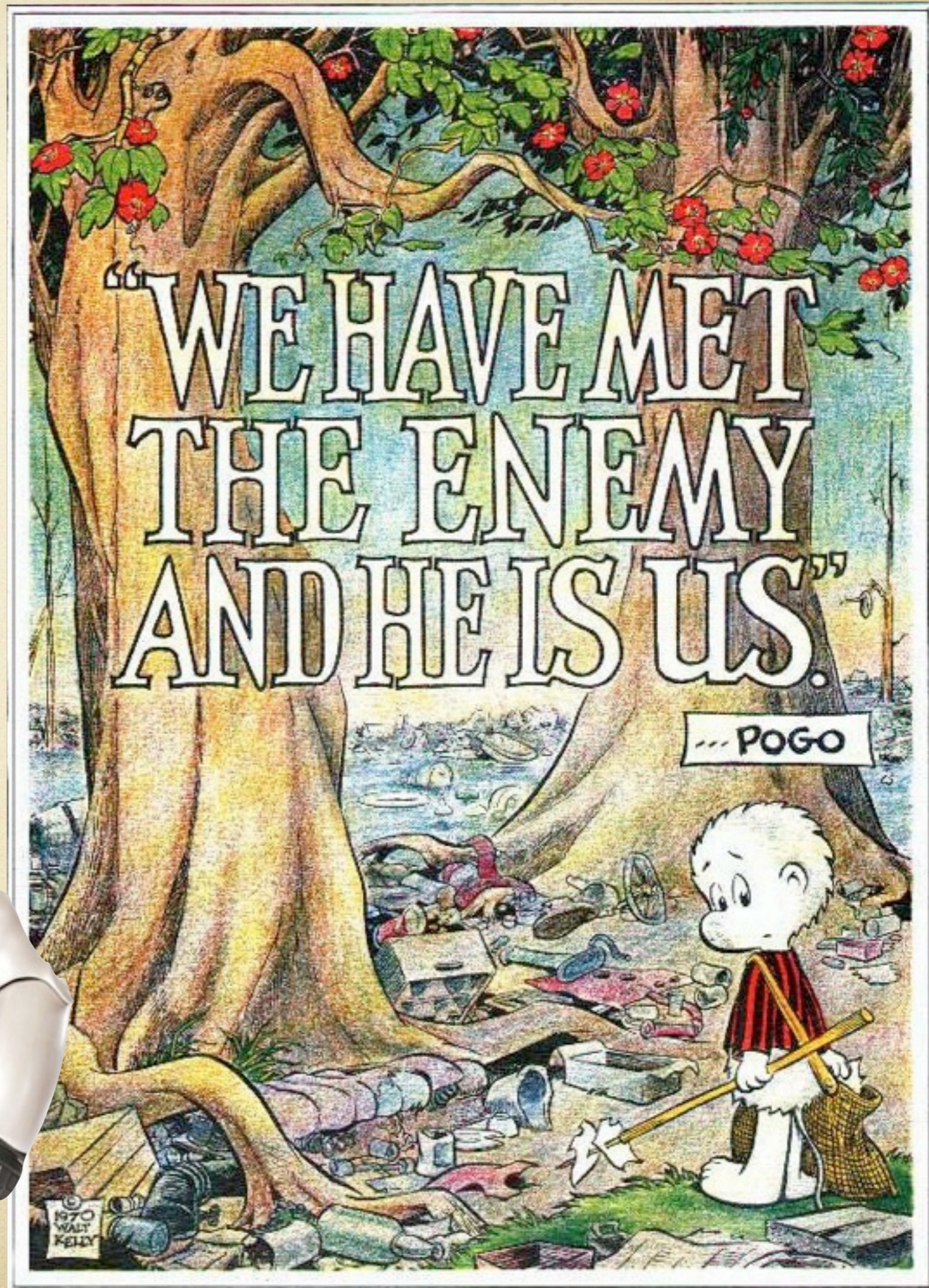
- Satellite \$ Budget = Launch Cost;
- Mass, Volume, Shape - all Determined by LV;
- Structure defined by launch loads and Launch Vehicle interface;
- Safety requirements set by LV (inhibits, materials, parts spec);
- Design to be launched batteries charged or (likely) discharged;
- Last access timing and design of access (those tiny doors);
- Orbit insertion / accuracy may drive propulsion requirements;
- Non-US launch + ITAR determine technologies incorporated in satellite.

## Mission Design

- Spontaneous /Responsive space impossible w/o responsive launch
- Low cost missions nonexistent without low cost launch
- SERB list driven by launch cost (and cost parity) and availability
- Many missions excluded by lack of reentry: materials, bioscience, manufacturing, space environment
- Satellite buildable independently - like PC - but not launch.  
=> *Space cannot mimic evolution of PC*
- **Rockets are Weapons:** Safety / Defense implications limit free market interest / exploitation of space



- Unachievable Requirements
- Documents never read
- Engineer Abuse
- Articles of faith
- web-less ipad
- Management by aliens



- Unachievable Requirements

- Lifetime

- Reproducibility

- Cost and Schedule (to better than  $\pm 50\%$ )

- Reliability

- Team independent



- Documents never read

- System Requirements Documents

- Management / Reliability / QA Plans

- Design Review Packages

- Detailed trade-offs and analyses

- Engineer Abuse

- They weren't English majors

- nor art, communications, poli-sci, econ



- Articles of faith (*a few just to get you started*)
  - parts cause systems failures
  - better parts make better systems
  - clean rooms and conformal coating protect spacecraft
  - more, and more extreme, testing is better
  - redundancy adds to reliability
  - lifetime can be calculated, more is worth paying for
- Management by aliens
  - small satellites are not small big satellites  
(soccer teams are not managed like Lufthansa)
  - management of small high tech programs  
and organizations is not generic (Proof by Jobs)
- Web-less ipad
  - What would a car look like without roads, service  
stations, hotels, cell phone, GPS, cities...

# In Sum: How to do it

- simple mission, short lifetime, small self-organized team, self-documentation, TIMs, no component lists, no tech drivers (specs vs. goal)
- Do it: 25 years after we stop laughing, create demand for min missions,



# between the (guide)lines leaving room for low cost

- Cost is 95% determined before the program starts
- Low cost is impossible without containing the size of the program and thus the work needed to be done
- Regarding the remaining 5%
  - Components without Space Q, heritage, radiation qual and test, material conformance
  - Construction methods (connectors, cabling, fasteners)
  - Less formal subsystem testing, less analysis,
  - More systems testing but in less conventional ways
  - Limited or zero use of clean rooms (by design)
  - Spec and requirements control (e.g. rad tolerance)
  - Rethinking reliability:
    - friend or enemy?    ● scaling laws: parts vs. complexity
  - Reviews: vs. TIMs

# more room for low cost

- Everyone is anti-paperwork (but pro documentation)
  - Reduce / eliminate reviews
  - only certain docs (ICD) synthesized
  - the rest are work byproducts (designs, analyses, code)
  - and some are useful and painless (photos and videos)
- ODCs:
  - travel,
  - the wrong kind of contract flexibility: mission inflation
  - the wrong kind of contractual inflexibility:
    - option to change parts / design if necessary
    - negotiate specs / scope downward to contain level of effort
    - legalize phase overlap, illegalize incremental funding
  - geographical diversity is PC but PI (piscally inappropriate)
  - ditto teaming with large infrastructures / orgs (DSN)
  - launch and ops teams and other flag showing



# **In somma....**



**The Grapefruit Diet:  
designing, building, launching**