

Faster, Better,  
but most important,  
Much, Much Cheaper

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Problem: spaceflight is too expensive:

- Launches are too expensive.
- Spacecraft are too expensive.
- Payloads are too expensive.
- Operations are too expensive.

Numbers are not just too big, but too long—too many digits!

*Large* reductions are needed.

# How did this happen?

## Comparison of two numbers:

- asking price
- offered price

## Asking price stable or rising slightly:

- Precautions accumulate.
- More ambitious missions.

## Offered price sharply down:

- Cold War is over!
- That fact might seem obvious and irrelevant. It's neither.

## Why pay for spaceflight?

Public doesn't care that much:

- Can sell some of it on science, and some on technology;
- Plus some on spectacle;
- But total \$ ends up being small.

Superpower competition big \$\$\$:

- Space race sometimes explicit.
- National pride an issue regardless.

## What need for chest-beating now?

Recent management fiascos haven't helped:

- Shuttle wasn't good.
- Hubble was embarrassing.
- Space station a massive disaster.
- Mars probes minor by comparison.

The change is *permanent*:

- The days of \$\$\$ missions are *over!*

Beware post-Apollo holding-pattern syndrome:

- The good old days will not return!
- Plans assuming that they will are dangerous delusions.

Forget incremental tuning:

- It's nowhere near enough.

Get used to new rules, or look for a new job:

- Business As Usual is dying fast.
- Many will have to look for a new job: fewer dollars = fewer people!

This applies to companies too:

- Dinosaurs starve.
- Innovators thrive... eventually.
- Transition is rough.

Same situation, different perspective:

- Radical reduction in launch costs often cited as crucial.
- Without it, must cut other costs.
- *With* it... must cut other costs!

Launch-cost effects mainly indirect:

- Tight constraints on mass etc.
- Difficult replacement = pressure for high reliability.
- Lack of proper in-space testing makes reliability hard to achieve.

Other things must change to take advantage of cheaper launches.

Need much cheaper spacecraft.

Need to operate them cheaply too.

When launch costs exceed spacecraft and operations costs, we're winning.

We're far away from that now.

Can it be done? Yes.

## MOST (Microvariability and Oscillations of STars)

- Small Canadian astronomy satellite
- Pegasus-sized (Pegasus \$15-20M)
- MOST design, develop, build, test, operate 1 yr: <\$3M (hard limit)

Not flown yet, but:

- Flight hardware under construction
- On specs, on time
- *On budget!*

MOST is a favorable case:

- Cutting-edge astronomy feasible with small telescope in right orbit.

But seems adaptable to bigger things:

- Use for other astronomy missions being studied.
- Derivatives being studied for small planetary missions.
- Both seem feasible.

Other cheap smallsat efforts yielding similar results.

# Can everything be done this way?

Probably not, but:

- Methods always limit feasible goals.
- New funding situation = new limits.
- Do occasional bigger projects as scaled-up small ones?

Do big things in small steps:

- Build on past work to make future projects easier.
- Requires programs, not just projects.
- Requires concentration of effort.

Better tools and technology make projects smaller:

- Need efforts to improve tools and technology.

Accomplish something rather than attempting everything!

# The New Space Order:

- Limit goals.
- *Faster* is key.
- Do it right.
- Learn from the past.
- Run it well.

## Limit goals (1)

Engineering constraints are important:

- Do what you know how to do.
- Accomplish something rather than attempting everything.
- Limit per-mission optimization.

Expand constraints with:

- Technology missions
- Secondary experiments

## Limit goals (2)

Possibilities, budgets, risks determined bottom-up:

- Engineering drives mission, not vice-versa.
- Engineers and operators involved early, buy into goals.

Dollars dominate goals:

- Overruns mean *goal cuts*.

## *Faster* is key (1)

Above all, do projects quickly:

- Requires small teams.
- Get real results, not simulations.
- No time to dither or optimize.
- No time to build empires.
- No time for personnel turnover.
- No time for changed objectives.
- No time for budget oscillations.

## *Faster* is key (2)

Many of these things also give you *Better*, plus:

- No time to become obsolete.
- Fast results guide follow-ons.

And *Cheaper* too:

- No time to spend lots of money.
- Small team needs fewer documents.
- Small team needs less management.

Do it right (1)

Streamline. Especially, write documents only to meet specific needs.

Resolve critical issues early.

Build things, don't study them.

Changing your mind is crucial.

Provide for large margins.

Do it right (2)

Build flight hardware early.

End-to-end testing.

Provide options but focus investment on normal case.

Selective redundancy.

Fly two! (And have a bonus plan.)

## Learn from the past

- People *have* built cheap satellites before.
- The Old Guard did have some good ideas.

## Keep your own past alive:

- Retain *teams*, use them again.
- Retain people.
- Personnel continuity is cheaper than documentation.
- Analyze experience, make sure lessons actually get learned.

## Run it well (1)

### Teams not groups:

- Small teams.
- Full-time people.
- Physically together.
- Regular meetings.

### Fewer but better people:

- Be selective.
- Look for broad expertise.

Same team throughout: they design, build, *and* operate.

## Run it well (2)

Need a chief designer:

- Knows *everything*.
- On board for full duration.
- Crucial to success.

Clear responsibilities:

- Do it right once rather than checking it ten times.

## Run it well (3)

### Misc.:

- Bearers of bad news are welcome.
- Reviewers should have a stake in mission success.
- Reward results, not effort.
- Avoid management fads: strive for competence, not gimmicks.

Getting there from here is tricky.

Need to change *how* things are done, not just what is done:

- Can't do same old things with half the time and half the money.
- Commanding organizations to change doesn't work.
- Must grow new organizations.

# Growing new organizations (1)

## Basic prerequisites:

- Good people.
- Challenges (but not impossibilities).
- Resources.
- Freedom to make mistakes.

Insulating them from old organization is tricky:

- Especially after the first big success.

## Growing new organizations (2)

Plant extras and thin them out:

- Competition works, central planning doesn't.
- Only death makes competition real.

Don't feed the dinosaurs:

- Open markets are crucial to new organizations.
- The dinosaurs will die anyway.
- Know whether your organization is a mammal or a dinosaur.

Getting there from here, P.S.:

We will need those cheaper launches...

## Conclusions:

- The world has changed.
- Adapt or die.
- Dinosaurs will die.
- Mammals are possible.
- They don't look like dinosaurs.
- Dinosaurs don't become mammals.
- You can grow mammals if you try.