Getting Off the Ground

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Space Manufacturing 14

Space Studies Institute

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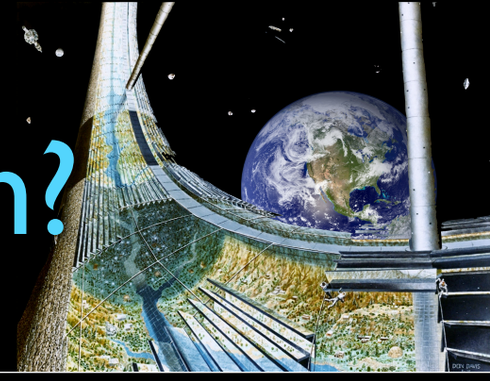
Why Has This Been A Problem?



Cost of access to LEO constrains everything we wish to do in space

Once in orbit you are "halfway to anywhere"

Nothing else matters as much as low-cost, routine and reliable LEO access

What are the Biggest Challenges?

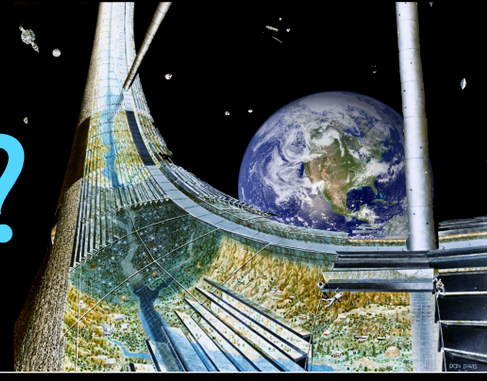
Market demand, financing and naive regulation

Not technology
Not "destinations" (i.e., Constellation)
Not heavy lift
Not enabling legislation
Not "spaceports" alone

Historically, NASA opposition was a factor

(No longer a dominant concern...now we need to worry about Congress instead)

Why is Launch Expensive?



We throw LVs away

Do the math

We fly them only once

Reduces reliability

We don’t fly often enough

Overhead and development can’t be amortized effectively

“I’ve Tried A, I’ve Tried B, I’ve Tried C”

What’s been tried? E v e r y t h i n g .

Reusables vs. Expendables

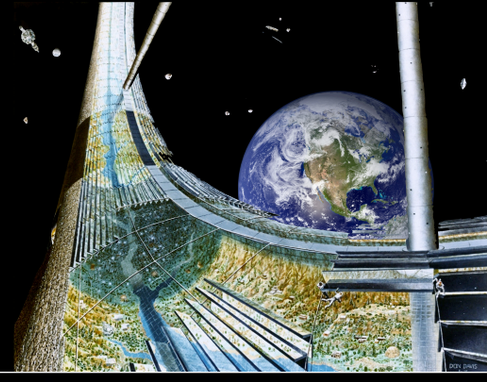
One stage vs. multiple stages

Ground, sea and air launching

Solid, liquid, hybrid & air-breathing propulsion

All gov’t funded; all private funded; public-private partnerships

What Has Worked?



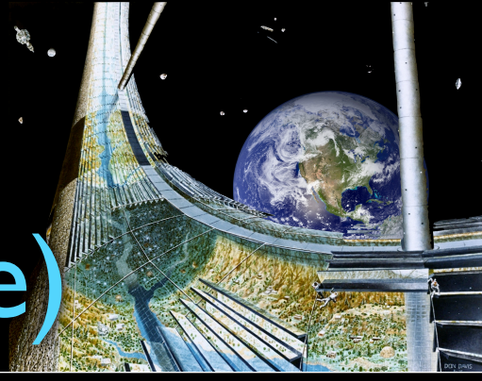
N o t h i n g .

(If we are talking about *real* cost breakthroughs – meaning prices a few times propellant costs...)

"It's the standing army, stupid!"

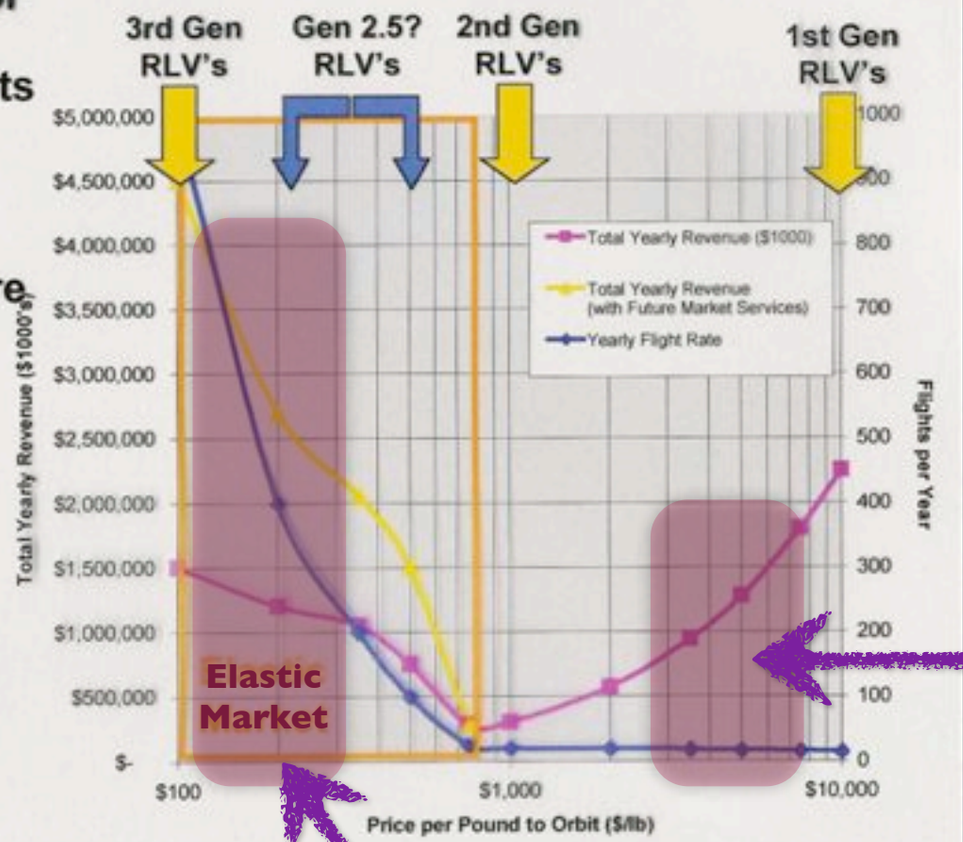
Universal Launch Alliance, Orbital and now SpaceX have succeeded in developing "commercial" rockets with a mix of private and public funding, but they have *not reduced* the cost of access sufficiently to expand the market.

The Elastic Market
(Total Revenue Does Not Increase)



Where *Can* We Go From Here?
One Option: Future Commercial Space…

- **Future Commercial Space (FCS) is our broad term for the elastic market that emerges once launch costs drop below ~$600 per pound.**
- **These new markets require the development, deployment and maintenance of a large, manned LEO infrastructure.**
- **The RLV design requirements for FCS are the same as NASA's**



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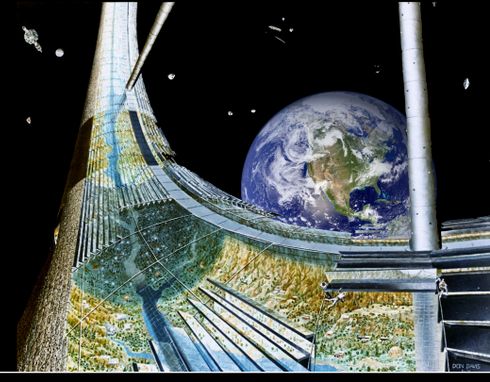
Current ELVs

Where we need to go

Slide Courtesy Dana Andrews, Andrews Space

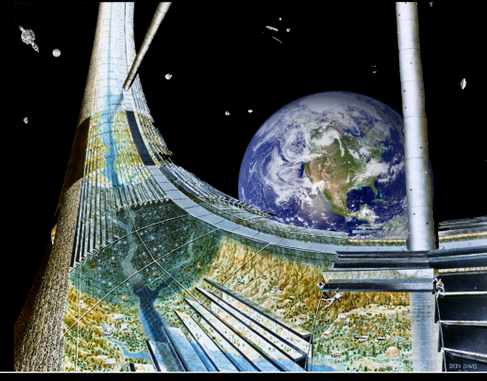
New Markets



"These new markets require the development, deployment and maintenance of a large, manned LEO infrastructure..."

– Dana Andrews

OK, So What Markets Will Deliver?



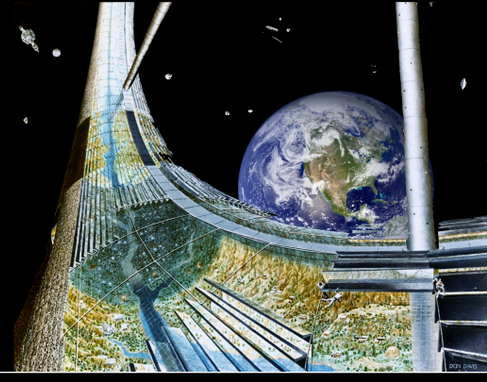
Near term "affirmative action missions" by NASA for ISS resupply, propellant depots, debris cleanup, exploration support

Medium term tourism, or "sovereign customers" (i.e., foreign governments) to private space facilities; tether infrastructure installation?

Long term, must be people – space settlement, opening the frontier including resource exploitation, exploration on a massive scale, and planetary defense

The challenge is bridging the gap

After Markets, What Are the Biggest Roadblocks?



Technical

No breakthroughs are required,

but ones that reduce risk or cost are welcome

Political

An end to pork and "cafeteria-filling" and

recognizing the role of the private sector

Legal

Sensible engineering and science based vs. emotional regulation

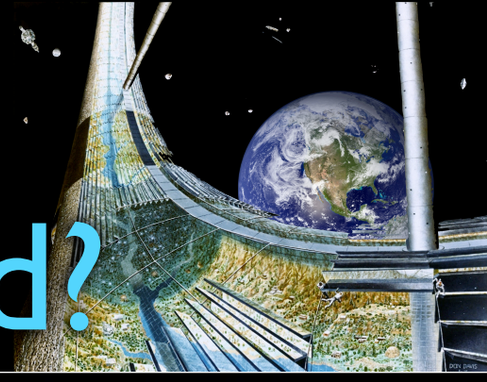
Financial

Where to begin? Macro issues; venture funding...

Social

We've been ready for the breakout for fifty years, nothing needs be done

After Markets, What Breakthroughs Are Needed?



Availability of Risk Capital & Investor Patience

Industry needs both (a role for NASA)

Paradigm/Perceptual Change

"Brother-in-law" problem, broken regulatory regime, ITAR

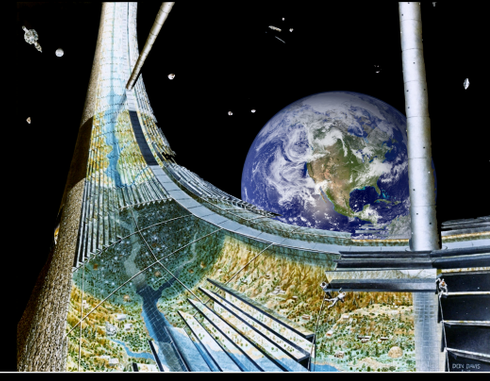
Certain technological advancements would be nice

Durable TPS, tethers in LEO, highly reusable engines

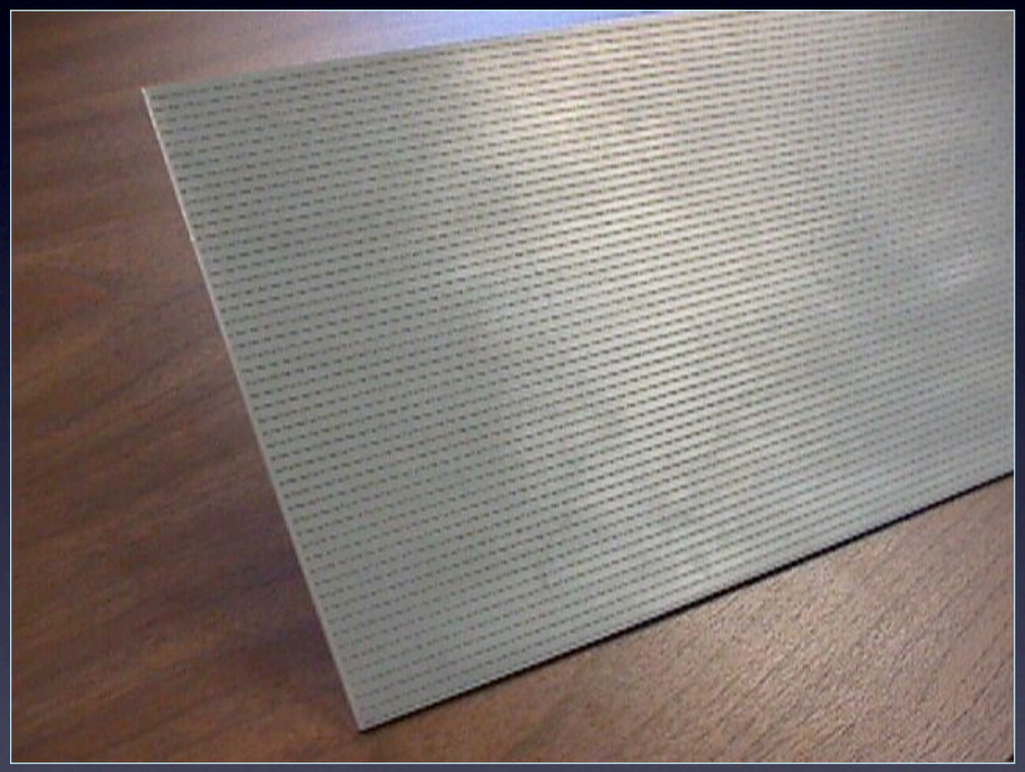
Some "breakthroughs" that would be useless

Scramjets or most air-breathing engines, "heavy lift"

RLV Technology for Routine Access

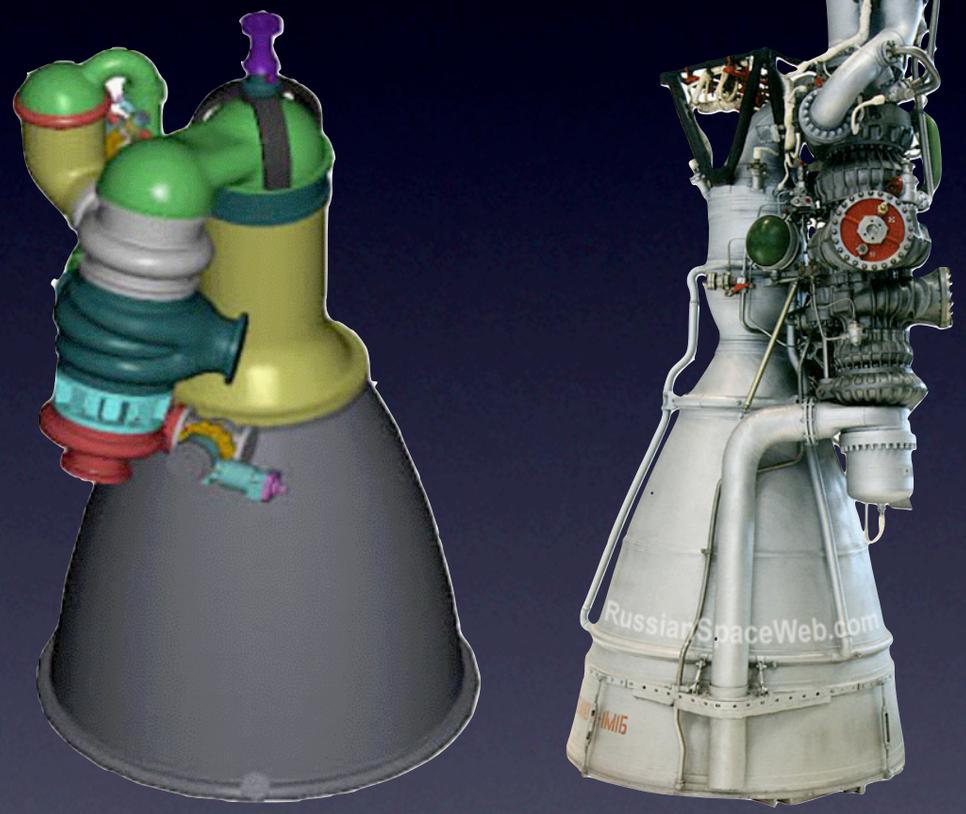


Active Fluid Cooling



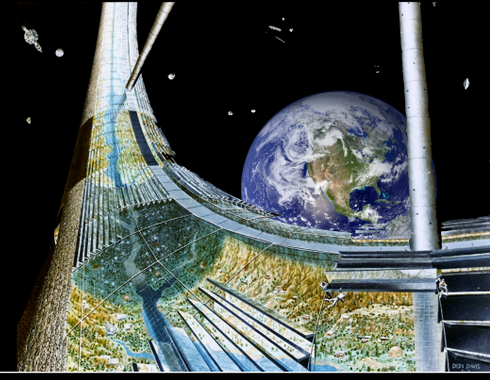
Active fluid cooling permits the use of conventional structures and components. Also allows hyperbolic orbit entry to Earth and aerobraking everywhere.

Highly Operable Engines



Long life rocket engines will reduce cost per flight via amortization of capital expense.

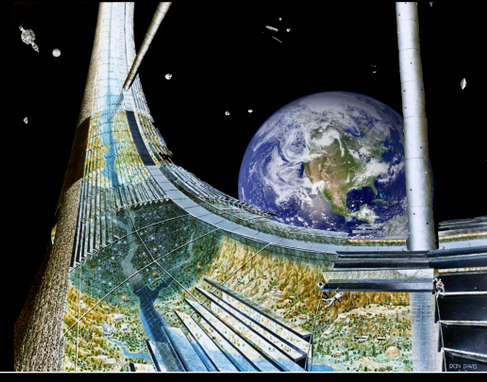
RLVs: Ground-Launched



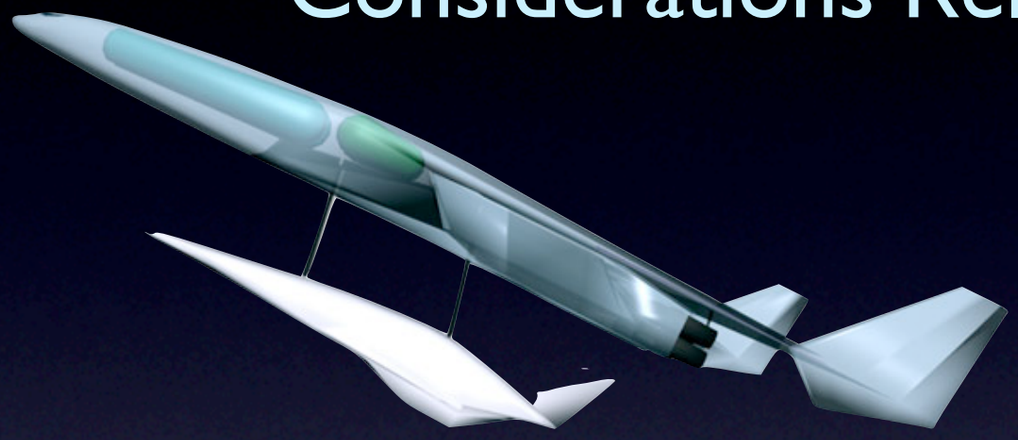
Considerations Relating to Ground-Launching

No significant constraint on GLOW
No significant constraint on diameter or length
Fairly easy to obtain near-SSTO performance

RLVs: Air-Launched

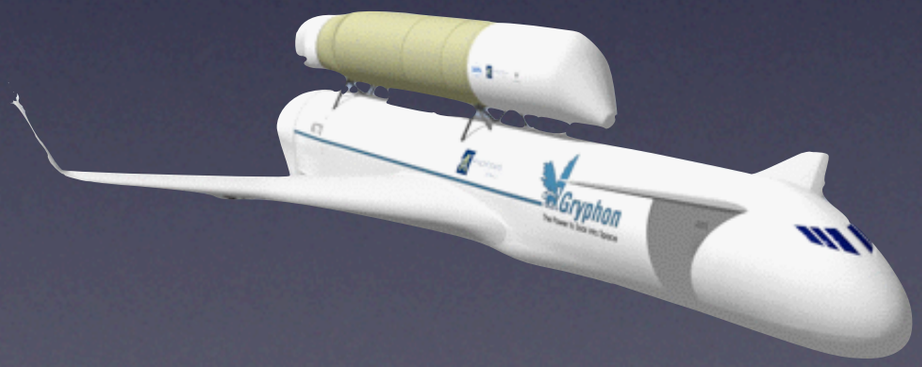


Considerations Relating to Air-Launching



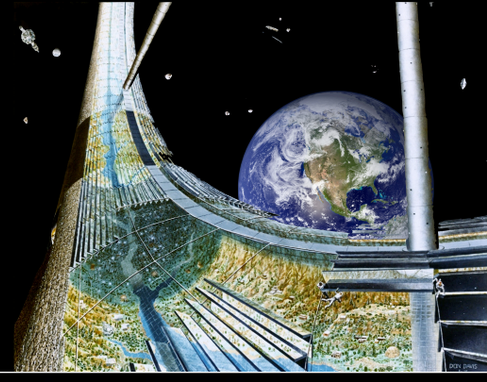
Potential that aircraft-like takeoff yields reduced range

First orbit rendezvous is easy & good match for tethers



Easier to achieve one stage to orbit (not counting aircraft)

What are Achievable Price Goals?



- $500 pound or less in the near term (5 years)

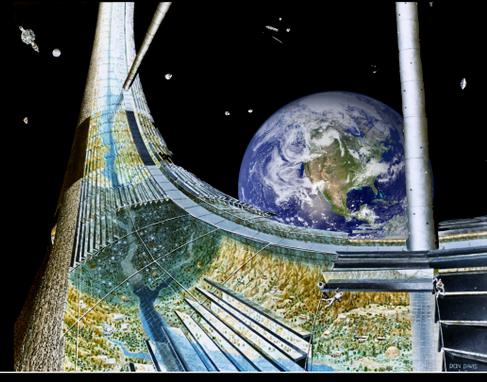
  Can be obtained with ELVs, flying once per week or a few times per month, reusing engines and avionics

- $100 pound or less in the long term (10-15 years)

  Can be obtained only using an RLV, 100% reusability, high flight rate (daily) and with improved TPS plus highly operable, long-life engines

Assumptions: RDT&E fully amortized up front by public-private partnership (grants, long term loans) and manpower loading is business-optimal not political-optimal.

Take Home Message



- Markets & flight rate – not technology – are enabling
- Cash flow is needed more so than investment
- Sadly, some “affirmative action” is needed from gov’t
- Improved engines and TPS are desired, not required
- No single answer for vehicle type, but less is more
- “Cheating” via tethers is a good cheat