

# Building Codes for Off-World Applications

Patrick Anselmo Donovan at ISDC 2018



SPACE  
COOPERATIVE

# Today's Goal

# Three Basic Assumptions:

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1. Our activity in space improves life for people here on Earth...

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2. Human life is worth protecting...

# Three Basic Assumptions:

1. Our activity in space improves life for people here on Earth,
2. Human life is worth protecting,
3. ...and we all put a price on it.

# How would I benefit from a Multiplanetary Building Code?

# Benefits of a Space Building Code

1. balance the reach of industry with the need for safety,
2. Accelerate space industry growth, and
3. inform and accelerate terrestrial environmental policy

# What are building codes?

*“The purpose of this code is to establish the minimum requirements to provide a reasonable level of safety... through [various methods]...to life and property from...hazards attributed to the built environment.” - 2015 International Building Code*

# Areas Covered by Building Codes

- Structural engineering
- Emergency access and exit
- Lighting and ventilation
- Natural gas delivery and usage
- Mechanical equipment
- Plumbing
- Property maintenance
- Fire prevention
- Energy conservation
- Modifying existing structures

# Why isn't there a space building code already?

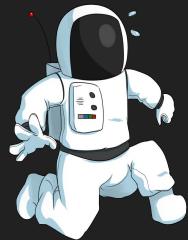


BUSINESS

ECONOMICS

REGULATION

PHYSICS



## Space Industry



BUSINESS

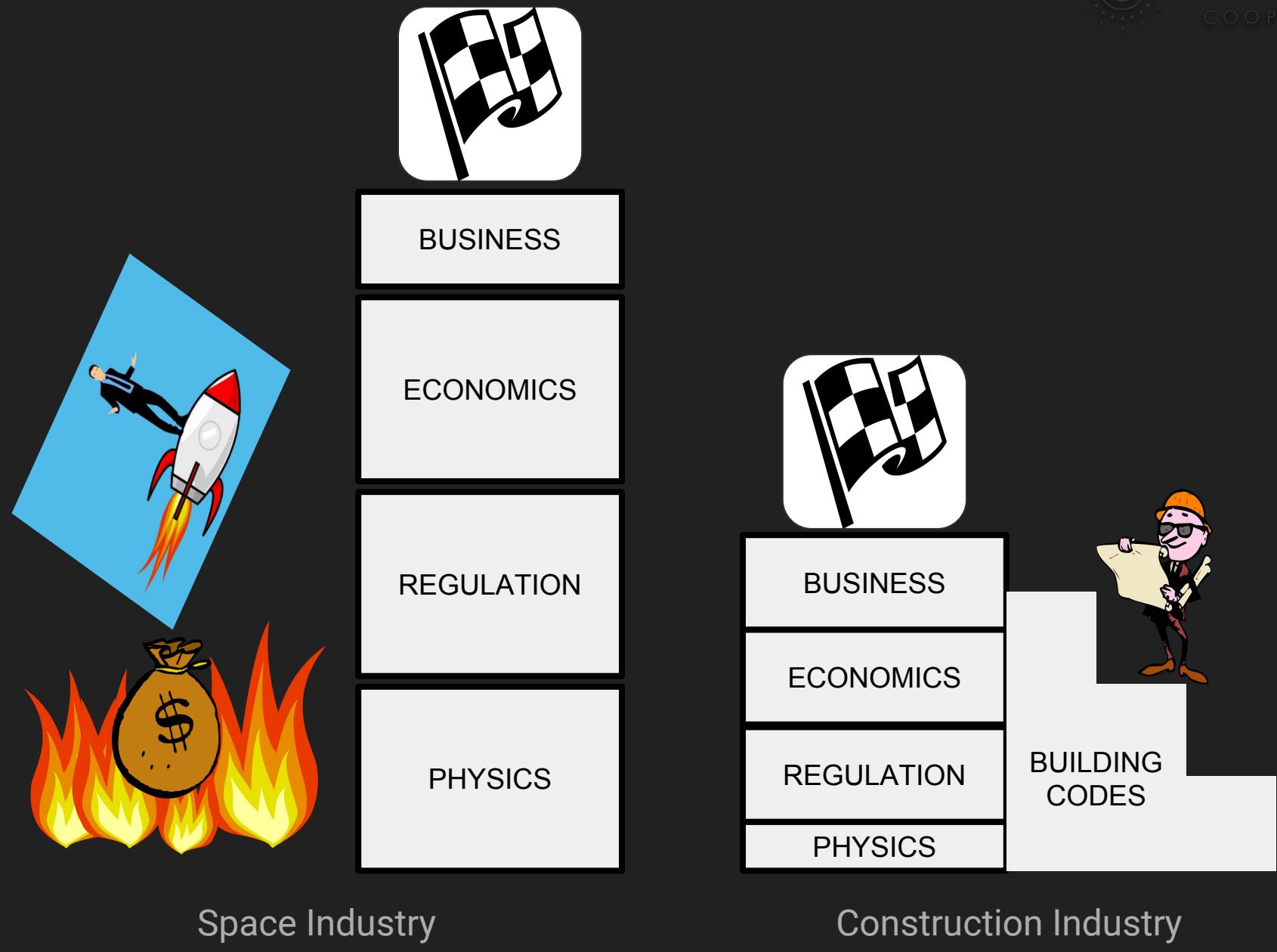
ECONOMICS

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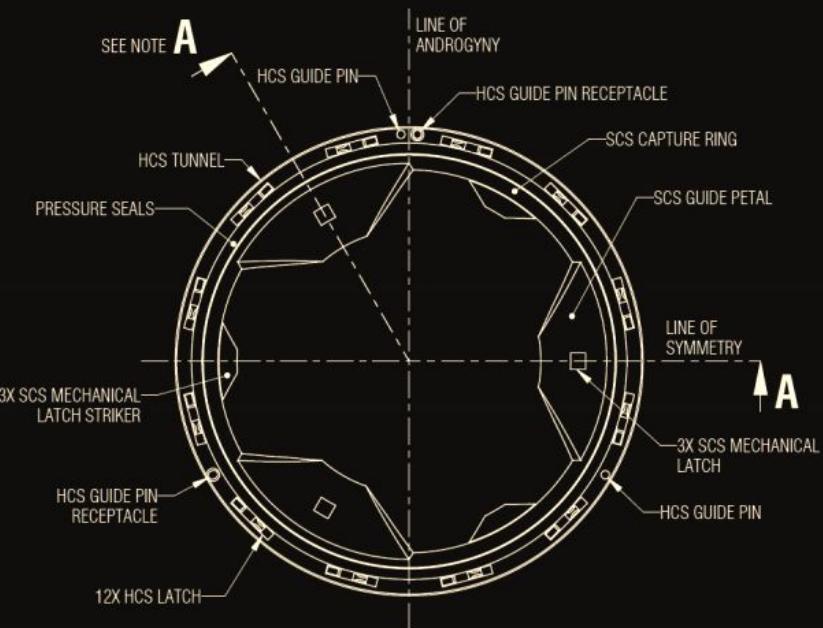
PHYSICS



## Construction Industry







Note: Refer to Figure 3.1.1.1-2 for Section A-A.

FIGURE 3.1.1.1-1 ANDROGYNOUS DOCKING INTERFACE – AXIAL VIEW



## 1U Cubesat

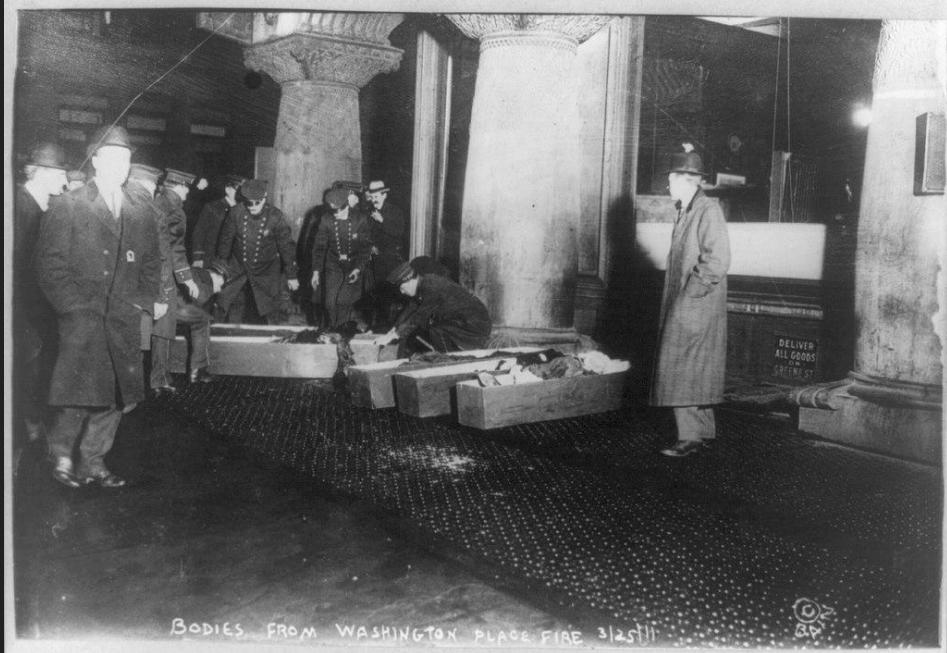


International Docking System  
Standard - Illustration by ISS MCB

NASA's Modular  
Common Space Bus

# Claim 1: Why Now

# “Building Codes are Written in Blood”



## Triangle Shirtwaist Factory Fire, 1911

Lesson: provide fire-resistant egress path

## San Francisco Earthquake & Fire, 1906

Lessons: numerous related to fire and seismic risk



U.S. Firebombing of Tokyo, 1945



WTC Tower 1 Collapsing, 2001



Los Angeles Apartment Buildings  
in 1994, "*Built to Code*"

Lesson: don't allow apartment  
buildings to be on stilts

Haitian Homes in 2010  
Lesson: enforce a building code

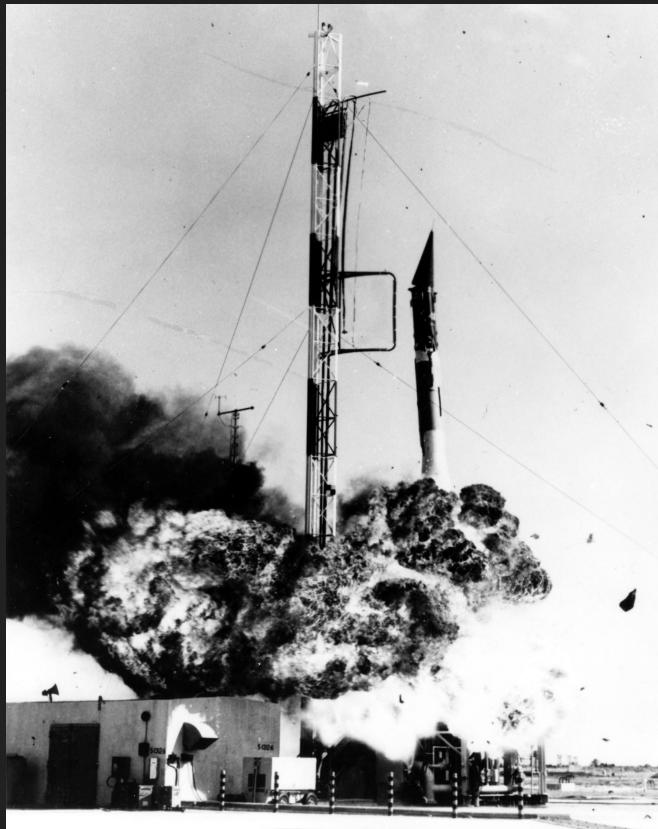


## Challenger OV-99, 1986

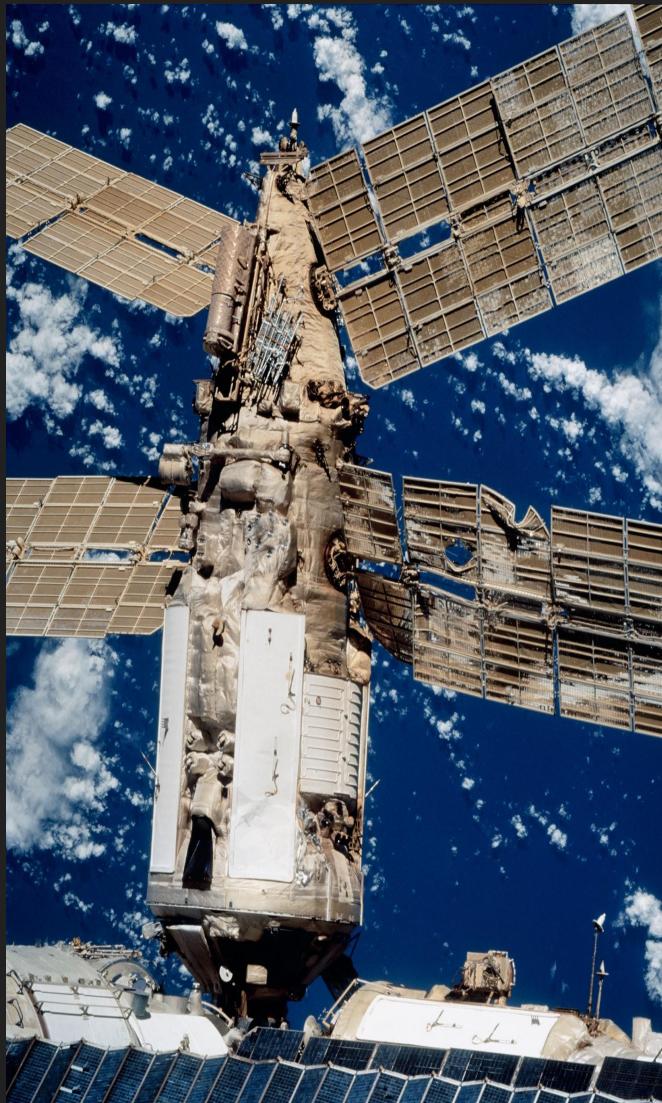
Lesson: only operate within limits established  
by testing

Apollo 13 CSM, 1970  
Lesson: be careful with  
insulation, wiring, and LOX

# Isn't it a bit early?



## Vanguard Launch, 1957



## Mir Collision Damage, 1997

# Counter-Claim: It's Too Early

Supporting Claims:

# Counter-Claim: It's Too Early

Supporting Claims:

1. Not enough evidence

# Counter-Claim: It's Too Early

Supporting Claims:

1. Not enough evidence
2. Nobody is asking for it

# Counter-Claim: It's Too Early

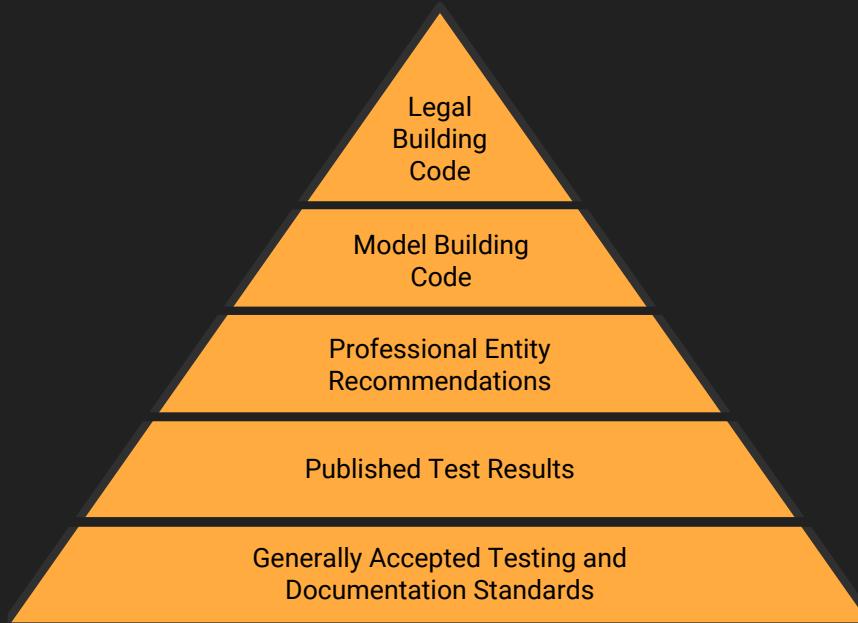
Supporting Claims:

1. Not enough evidence
2. Nobody is asking for it
3. It would be unenforceable

# Counter-Claim: Not Enough Evidence

## Terrestrial Status Quo

- Code revised every 3 years
- References revised every 3-5 years
- New test data constantly incorporated
- Changes to:
  - Materials
  - Design goals
  - Construction



# Counter-Claim: Nobody is Asking for It

“Engineers shall hold paramount the safety, health and welfare of the public...”  
- ASCE Code of Ethics

“Engineers shall act in professional matters for each employer or client as faithful agents or trustees...” - ASCE Code of Ethics

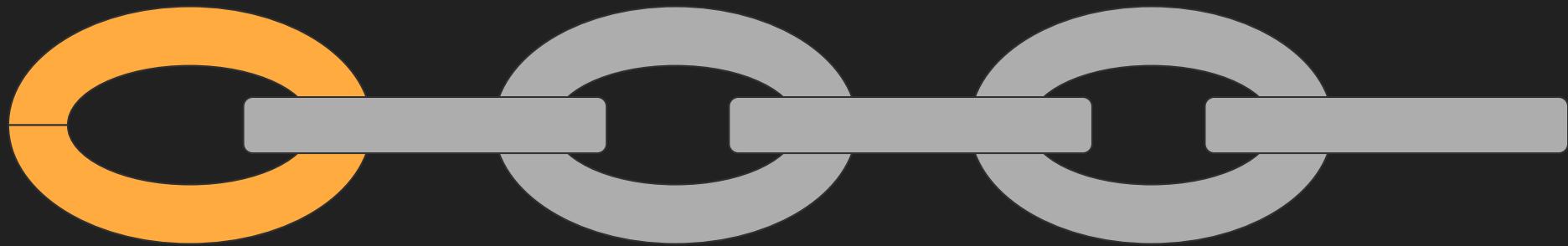
# Indirect Economic Beneficiaries

## Construction Industry

- Private investors

## Space Industry

- Private investors



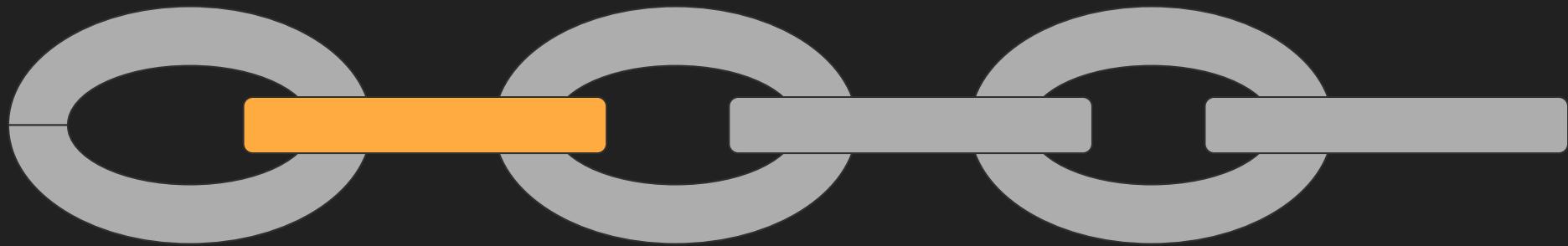
# Indirect Economic Beneficiaries

## Construction Industry

- Private investors
- Banks

## Space Industry

- Private investors



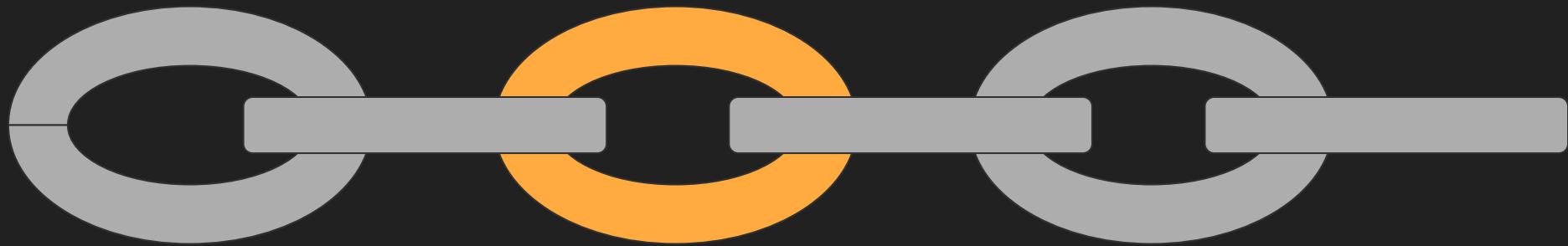
# Indirect Economic Beneficiaries

## Construction Industry

- Private investors
- Banks
- Insurers

## Space Industry

- Private investors
- Insurers



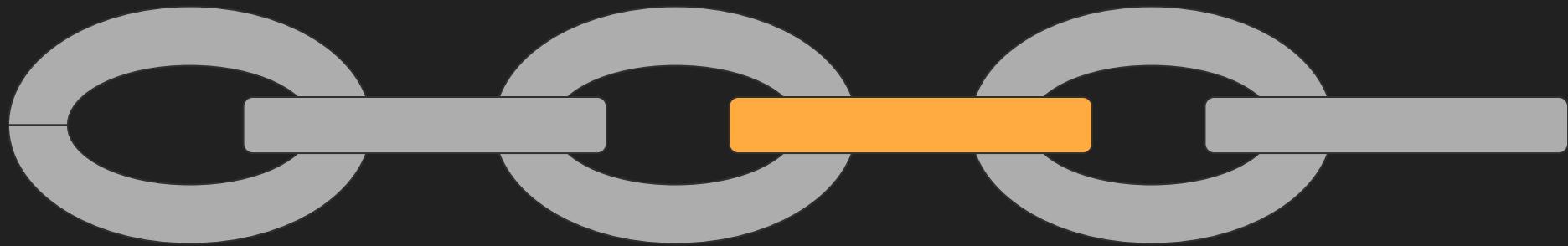
# Indirect Economic Beneficiaries

## Construction Industry

- Private investors
- Banks
- Insurers
- Regulators

## Space Industry

- Private investors
- Insurers
- Regulators



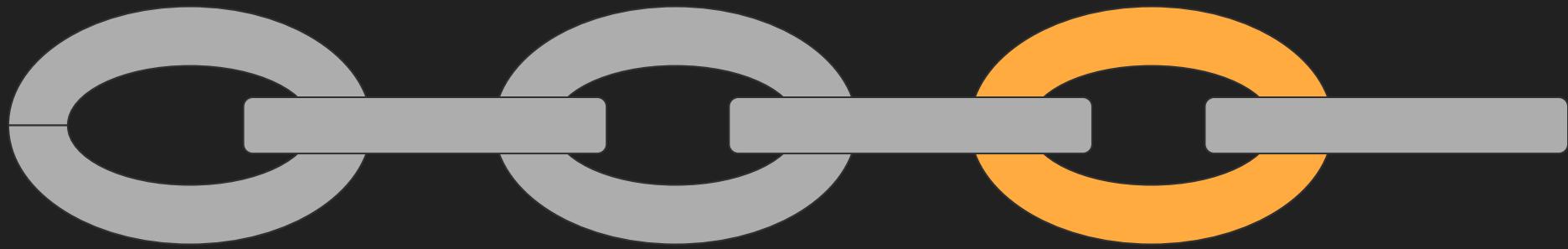
# Indirect Economic Beneficiaries

## Construction Industry

- Private investors
- Banks
- Insurers
- Regulators
- Component manufacturers & distributors

## Space Industry

- Private investors
- Insurers
- Regulators
- Component manufacturers & distributors



# Counter-Claim: It's Unenforceable

# Building Code Enforcement

On Earth

- Plan check
- Inspectors
- Engineers

In Space

?

# Counter-Claim: It's Too Early

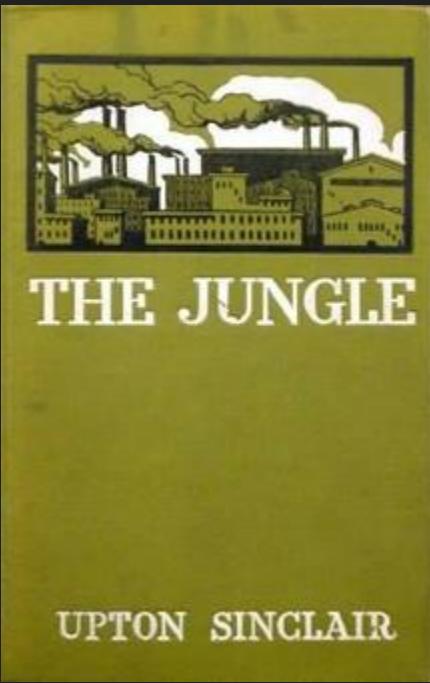
## Supporting Claims:

1. Not enough evidence
2. Nobody is asking for it
3. It would be unenforceable

## Responses:

1. Building codes are not static
2. Economic stakeholders should be asking for it
3. The bottleneck of launch providers provides an easy enforcement opportunity

# Claim 2: Balance Capability & Safety





# Code Conformity ≠ Uniformity



# Claim 3: Accelerate Space Industry Growth

## Commercial space activity:

2005 to 2014: doubled in size

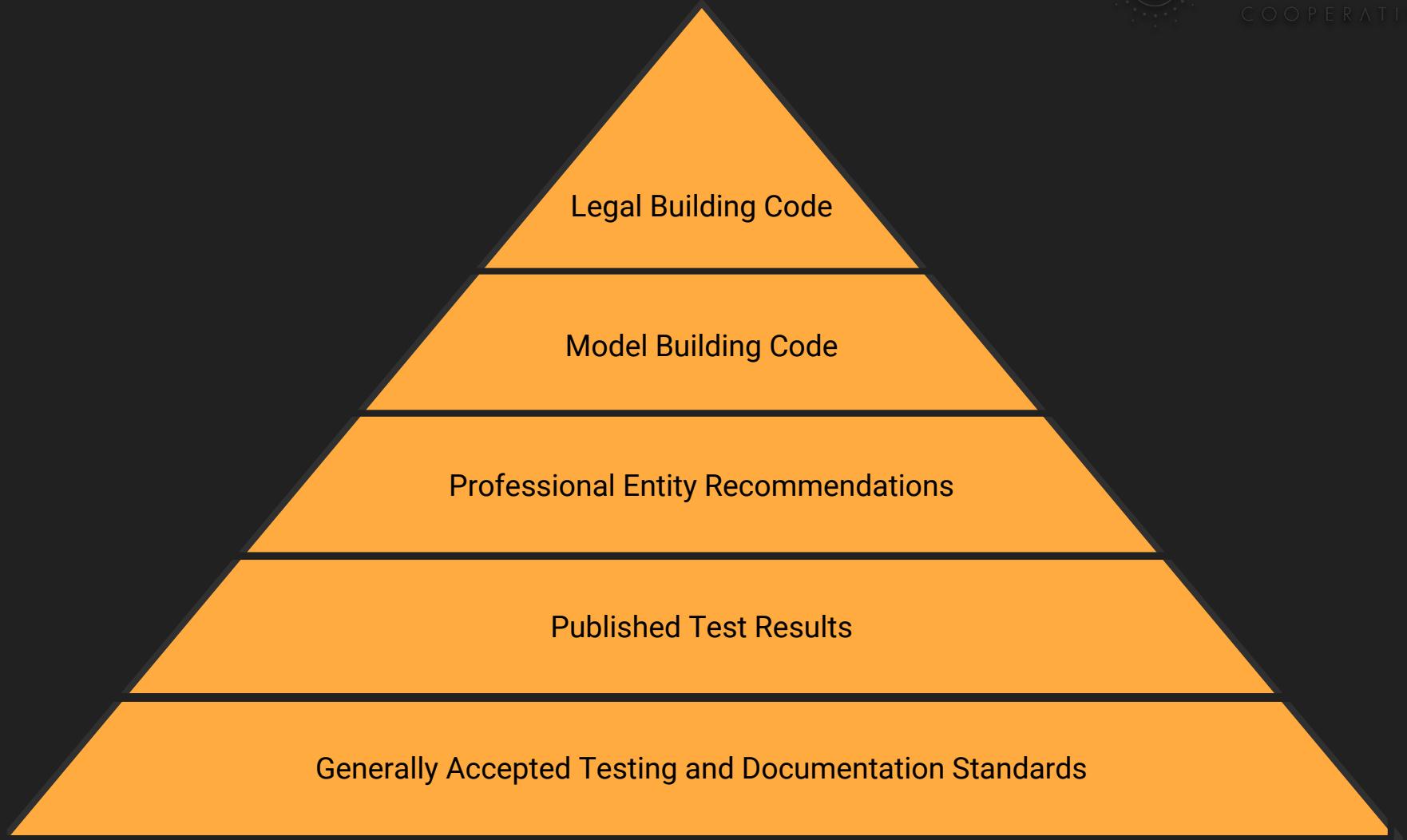
2013-2014: 12.9% non-U.S. growth

## Global aerospace industry:

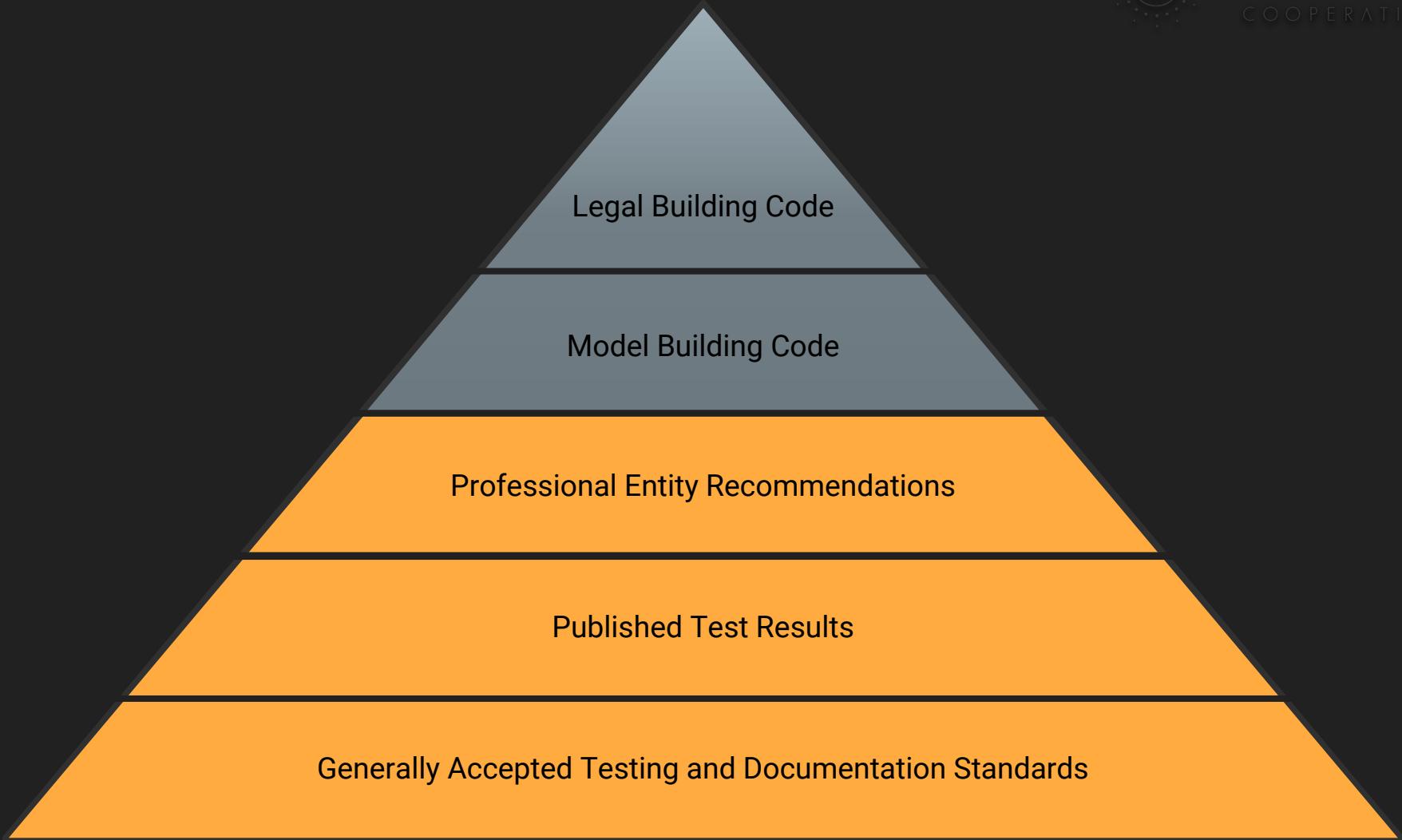
2018: expected 4.8% growth



## NASA Mission Control During Expedition 47



## Current Conceptual Foundation for Building Codes



## Current Conceptual Foundation for a Space Building Code

# Claim 4: Improve Life on Earth

# Assumptions

1. People on Earth face environmental problems comparable to those in space
2. In-space communities will
  - a. Document how they operate
  - b. Refine and develop ECLSS hardware
3. Some of their work will be applicable to Earth



# Terrestrial Environmental Problems



## Assumption 2: In-space communities will

- Document best practices for environmental resource management
  - Refine and develop ECLSS hardware

**Best practice:** “*a procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread adoption*” - Merriam-Webster

**Environmental resource management:** “*a family of standards [that] ... (a) minimize how their operations ... negatively affect the environment...; (b) comply with applicable laws,...and (c) continually improve in the above.*” - ISO 14001

# Balance of Motivators

Less environmental regulation

- Powerful stakeholders
- Some governments
- Traditional market forces

More environmental regulation

- Weaker stakeholders
- Other governments
- Environmentalist considerations

# Balance of Motivators

Less environmental regulation

- Some investors

More environmental regulation

- Everyone else

# Off-World Environmental Economics

Conditions:

1. Everyone shares nearly the same desires for their environment
2. Resources are scarce
3. Improvements in environmental resource management benefit everyone

Result:

Traditional market forces motivate the development of *both effective and economical environmental resource management.*

# Assumption #3: applicability to Earth

# Possibilities for Advancement

- Aeroponic food production
- Water treatment
- Waste processing
- Recycling
- Photovoltaic power

# What would a Multiplanetary Building Code look like?

# Designing for Hazards

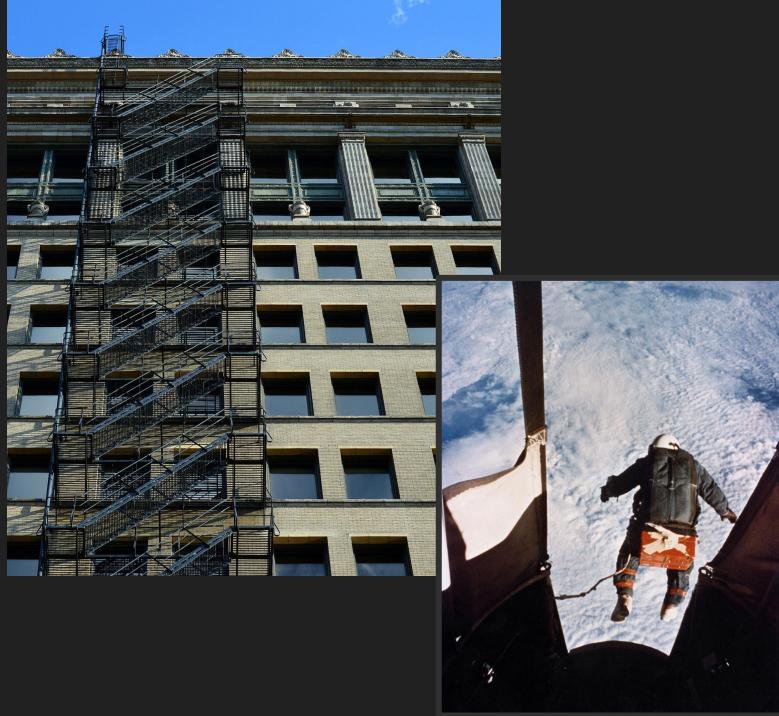
## Terrestrial

- Fire
- Earthquake
- High winds
- Floods
- Snowstorms
- Radiological
- Biological
- Mechanical failure

## Space

- Fire
- Emergency maneuvers
- Depressurization
- Atmospheric imbalance
- Radiological
- Biological
- Mechanical failure

# Responses to Hazards



“Ride out” - tornadoes and solar storms

“Get out” - fire and depressurization

# Code Content Sources

- Current building codes and references
  - IBC 2015 - International Building Code
  - ASCE 7-10 - Minimum Design Loads for Buildings and Other Structures
- OSHA
  - 29 CFR 1910 - General Safety and Health Standards
  - 29 CFR 1927 - Safety and Health Regulations for Construction
- NASA
  - TP-2015-218570 - Life Support Baseline Values & Assumptions Document
  - CxP 70024 - Constellation Program Human-Systems Integration Requirements
- U.S. Department of Defense
  - MIL-STD-1472G: Design Criteria Standard: Human Engineering
  - MIL-STD-1809: Space Environment [Design Parameters] for USAF Vehicles

# Who Will Write the Code?

- **Multinational Government**
  - UN Office for Outer Space Affairs (UNOOSA)
  - International Organization for Standardization (ISO)
- **National Government**
  - NASA
  - FAA
- **Private**
  - National Space Society (NSS)
  - International Code Council (ICC)

# Takeaways

1. Now is the time to start developing a Space Building Code
2. A Code should be developed because it will:
  - a. balance the reach of industry with the need for safety
  - b. Benefit the space industry, and
  - c. inform and accelerate terrestrial environmental policy
3. We have the means to start developing a Building Code



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