

Australian System Safety Conference 2019

Human Spaceflight – how safe is safe enough?

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- ✦ What is commercial human space flight and why is it different?
- ✦ Technical approaches to risk
- ✦ Cultural considerations around risk
- ✦ The future

What is Commercial Spaceflight?



By and For the Government

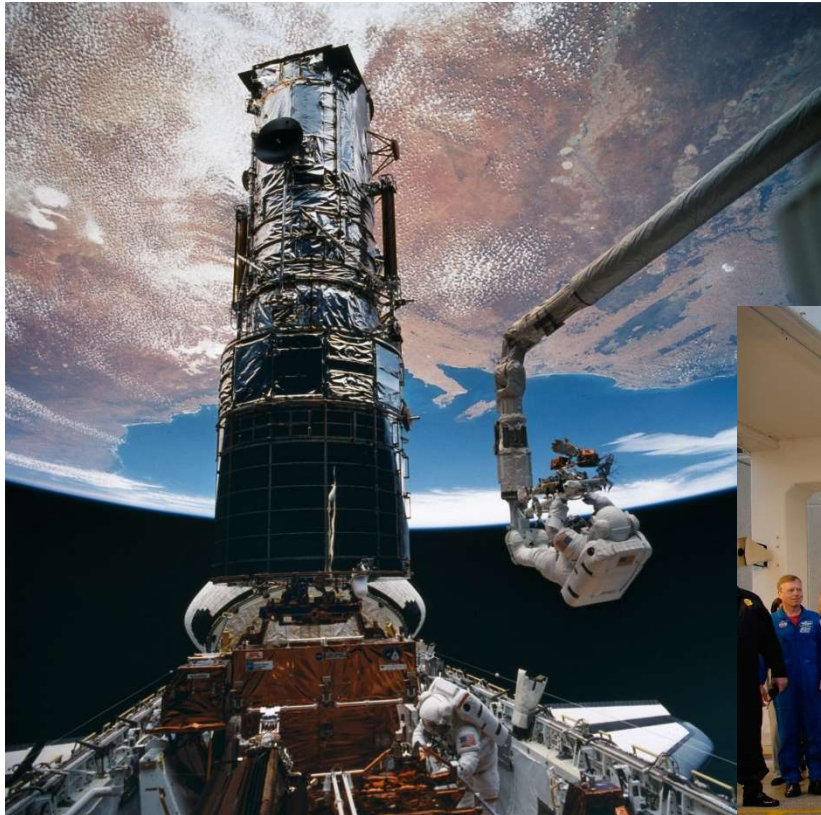


Image Credits: NASA





Risk rests with the operator, not the government*

*** Actually, under the Outer Space Treaty, third party damages always reside with government but generally companies must carry insurance**

Civil, Commercial, Defence Aviation/Space comparison

Private (FAA/CASA)



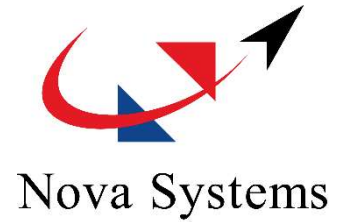
Defence (DoD)



Commercial (FAA/ASA)

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Civil, Commercial, Defence Aviation/Space oversight comparison



Private (FAA/CASA)



Defence (DoD)



Commercial (FAA/ASA)

Defence (DoD)



Civil (NASA/ASA)



Commercial (FAA/ASA)



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Technical Approaches to Risk

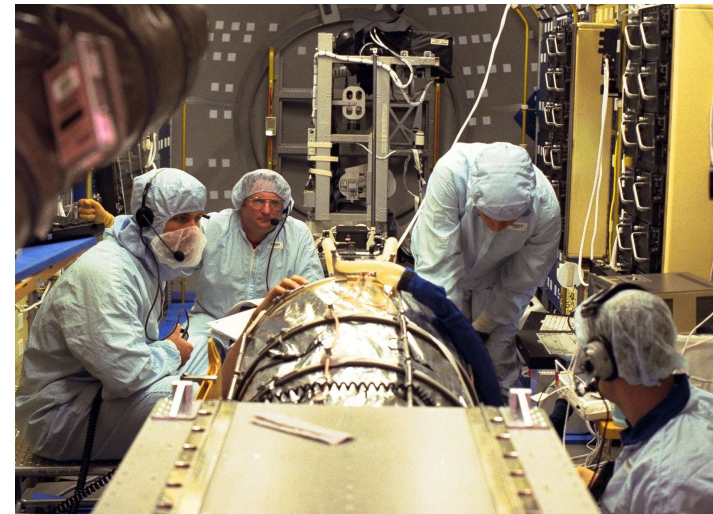
✦ “Certification” is current NASA approach

- ▼ “Attested as true, as represented, or meeting certain standards”
- ▼ “The process of providing a document attesting to a status”

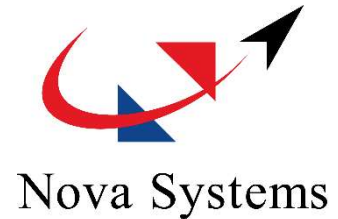
✦ Goes beyond “meeting requirements”
to the proof around having
met a requirement

- ▼ Evaluating test data
- ▼ Inspecting activities
- ▼ Reviewing models and analysis tools

Image Credits: NASA

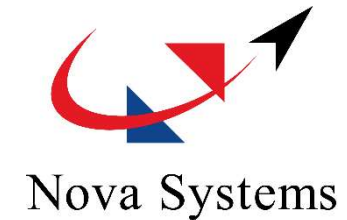


Technical Approaches to Risk



- Probabilistic Risk Assessment is an important tool for NASA
 - ▼ Evaluate risk of a complex system by breaking it down and assessing risk of individual areas, then combining risk
 - ▼ Uses fault trees, failure rates and probability data such as MTBF
- Example of misuse: design a vehicle 100 times safer than the Space Shuttle (early flights 1 in 9, later flights ~1 in 100 risk of catastrophic failure)
 - ▼ Impossible to confirm actual probabilities prior to significant flight hours
- However, PRA is an excellent tool for where to focus attention during design

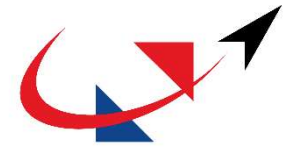
Technical Approaches to Risk



✦ “Risk-based” is current FAA approach to approving commercial rocket launches

- ▼ Focuses on specific aspects of design that entail risk
- ▼ Has limitations – licenses an operation, does not certify a design
- ▼ Does not assess design requirements – only performance
- ▼ Allows for significant amount of flexibility in different technologies
 - ▲ Most technologies being used commercially were government-developed

Orbital Space Flight



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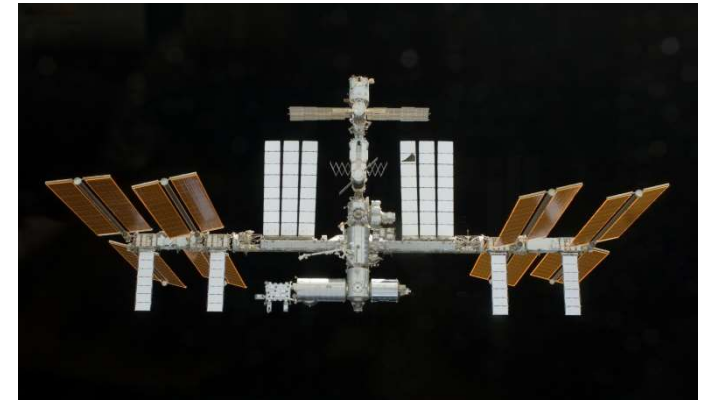
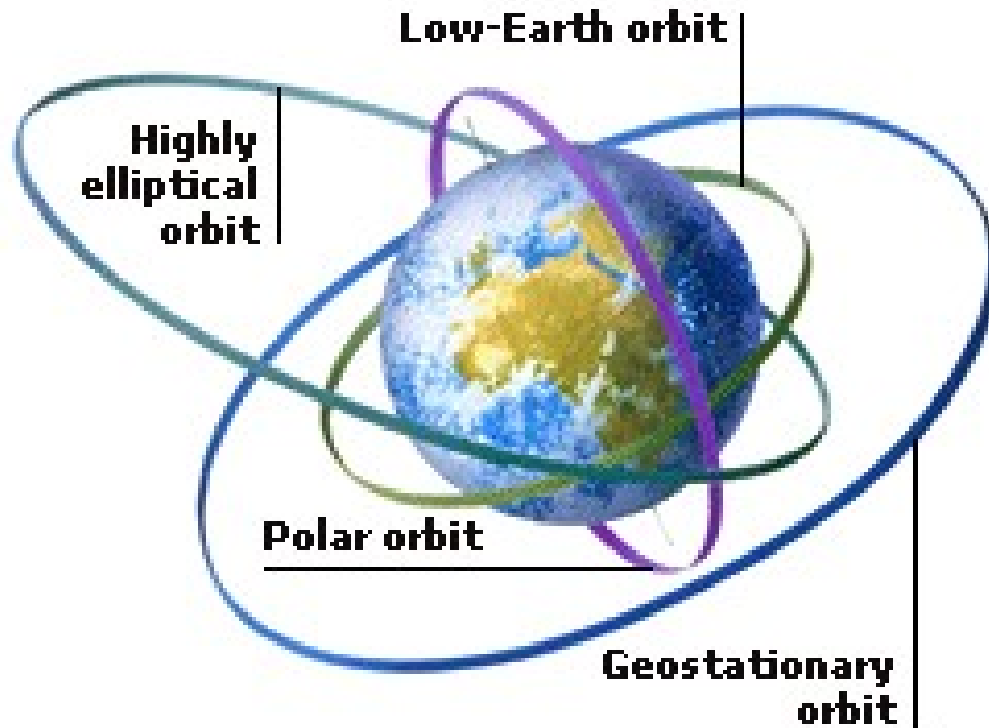


Image Credits: Wikimedia Commons, NASA

Sub-orbital Space Flight

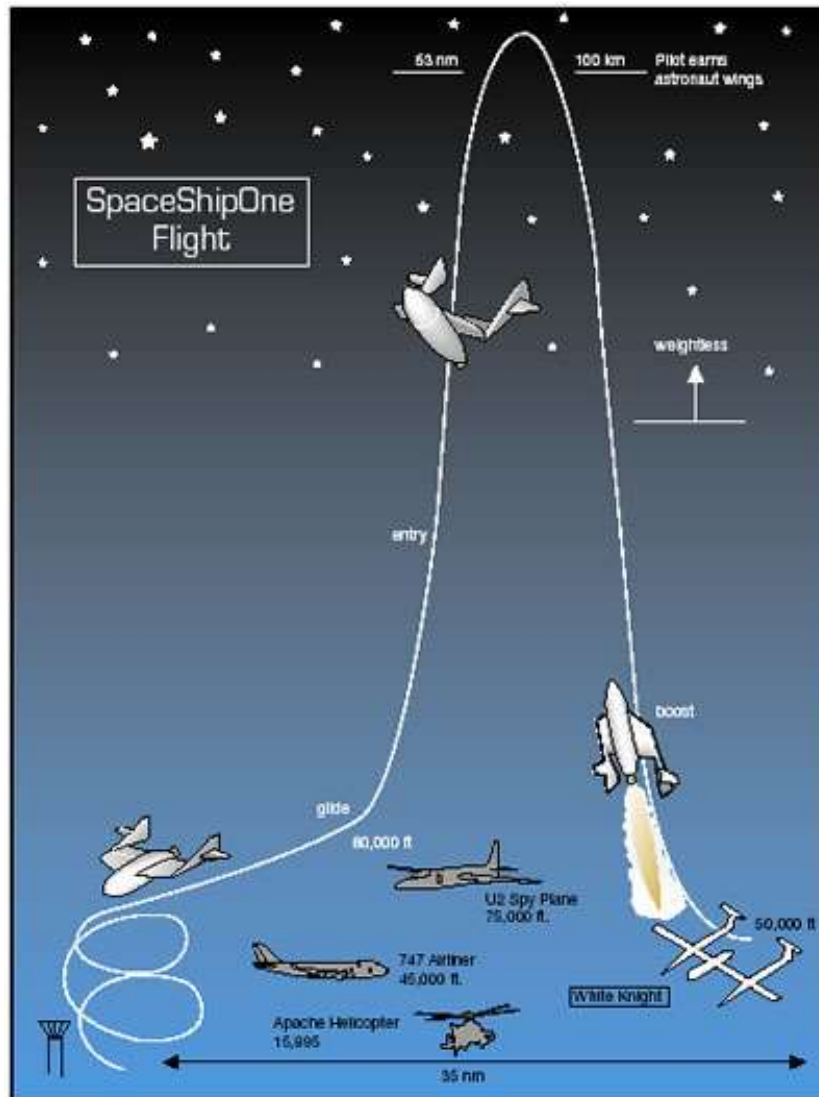
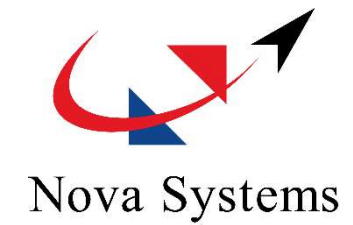
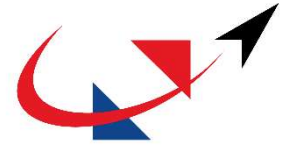


Image Credits: Virgin Galactic

Expendable Orbital Launch Vehicles



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SpaceX Falcon 9



**United Launch Alliance
Atlas and Delta**



**Northrop
Grumman
Antares**

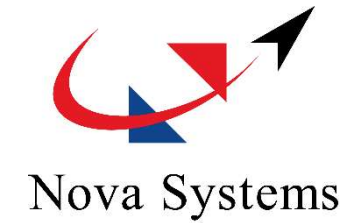


**Rocket Lab
Electron**



**Scaled Composites/Virgin Galactic
White Knight 2/SpaceShip 2**

Reusable Vehicles



**Blue Origin
New Shepard**



Falcon Heavy

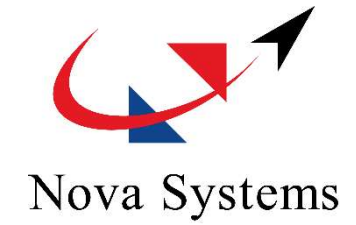
Image Credits: Wikimedia Commons, Blue Origin, Virgin Galactic, Stratolaunch



Human Commercial Spaceflight Risk



- ✦ Space tourists who have flown on Russian Soyuz were the first commercial space flight participants
 - ▼ Russian government responsible for training and oversight of mission
- ✦ Going forward these individuals will likely not have any government organization deeply involved in oversight, except third party risk assessment
 - ▼ Commercial Crew for NASA would be an exception



**“Commercial Crew”
Program
at NASA**

Human Commercial Spaceflight Risk



- ✦ FAA has authority in the US to oversee human spaceflight safety but restricted from regulations other than protecting public safety until 2023
 - ▼ Similar to an experimental air certificate
 - ▼ Example of public safety: having a qualified pilot on board
 - ▼ Spaceflight participants are NOT passengers under common carriage law – do they understand?
- ✦ Recommended Practices for Human Space Flight Occupant Safety published by the FAA in 2014 – guidelines only
- ✦ Standards organizations are working on some elements

Cultural Considerations Around Risk

All mishaps are not the same in the eyes of the public....



Image Credit: Wikimedia Commons



Image Credit: ABC News

Cultural Considerations Around Risk

Space Shuttle *Columbia* mishap 2003



Image Credit: NASA

SpaceShip 2 mishap 2014



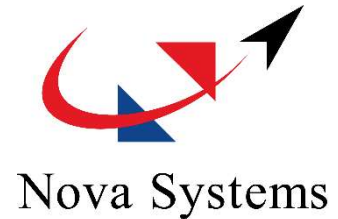
Image Credit: NTSB

Cultural Considerations Around Risk

SpaceX pad failure – flew next rocket 4 months later



Acceptable risk – public's view

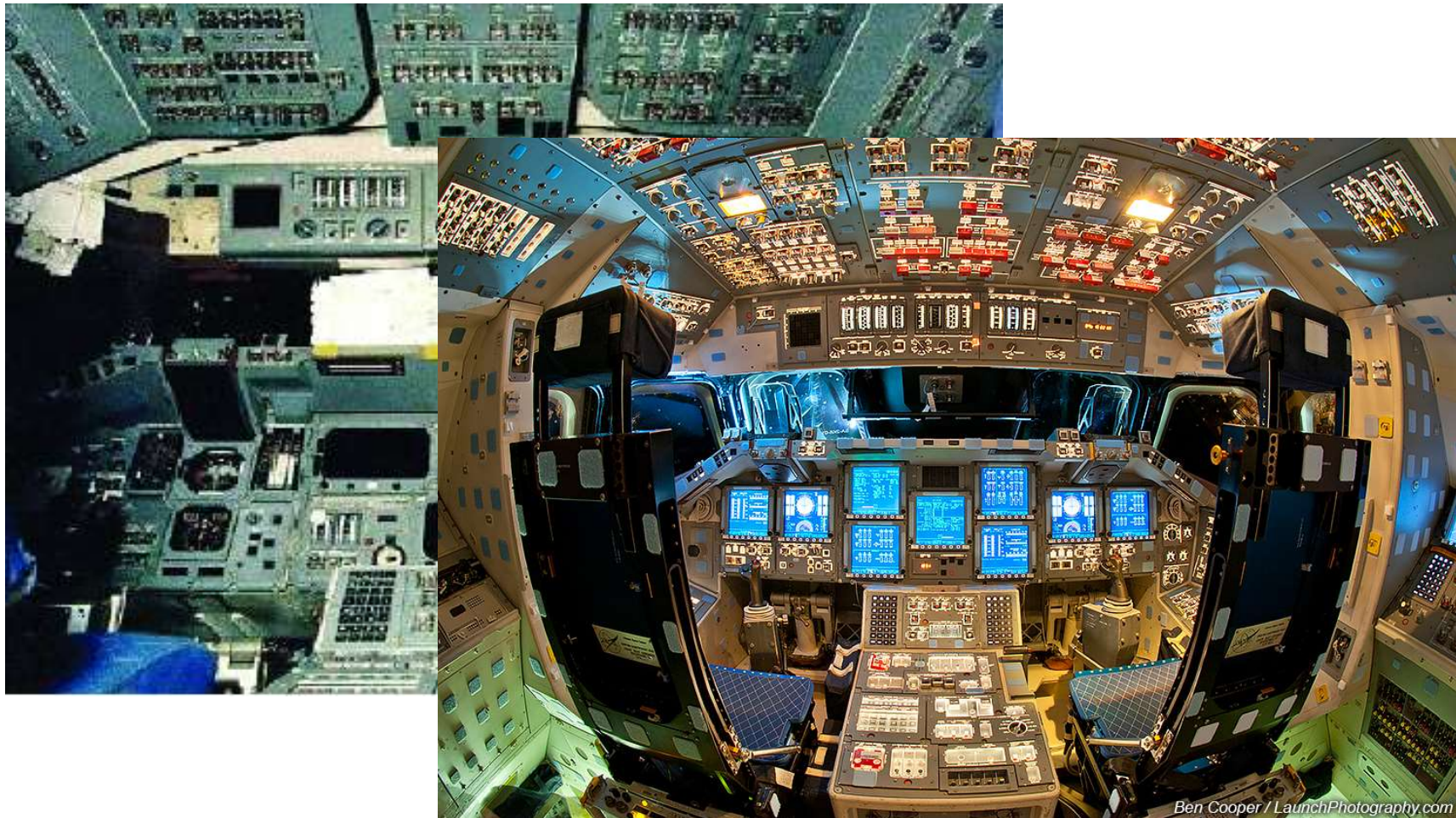


- ✦ .32% of hospitalized patients die each year from Adverse Drug Reactions (Journal of American Medical Association) – 100K people in the US
- ✦ Fatal airplane crashes .36 per million flights worldwide (500 people)
- ✦ US fatalities in car crashes per 100,000 people - ~ 11 (37,000 people)
- ✦ Maximum expected risk of third-party casualty from rocket failure per launch – 1 in a million per failure, total launch 100 in a million

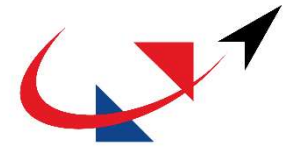
Autonomy in Human Space Flight



Autonomy in Human Space Flight

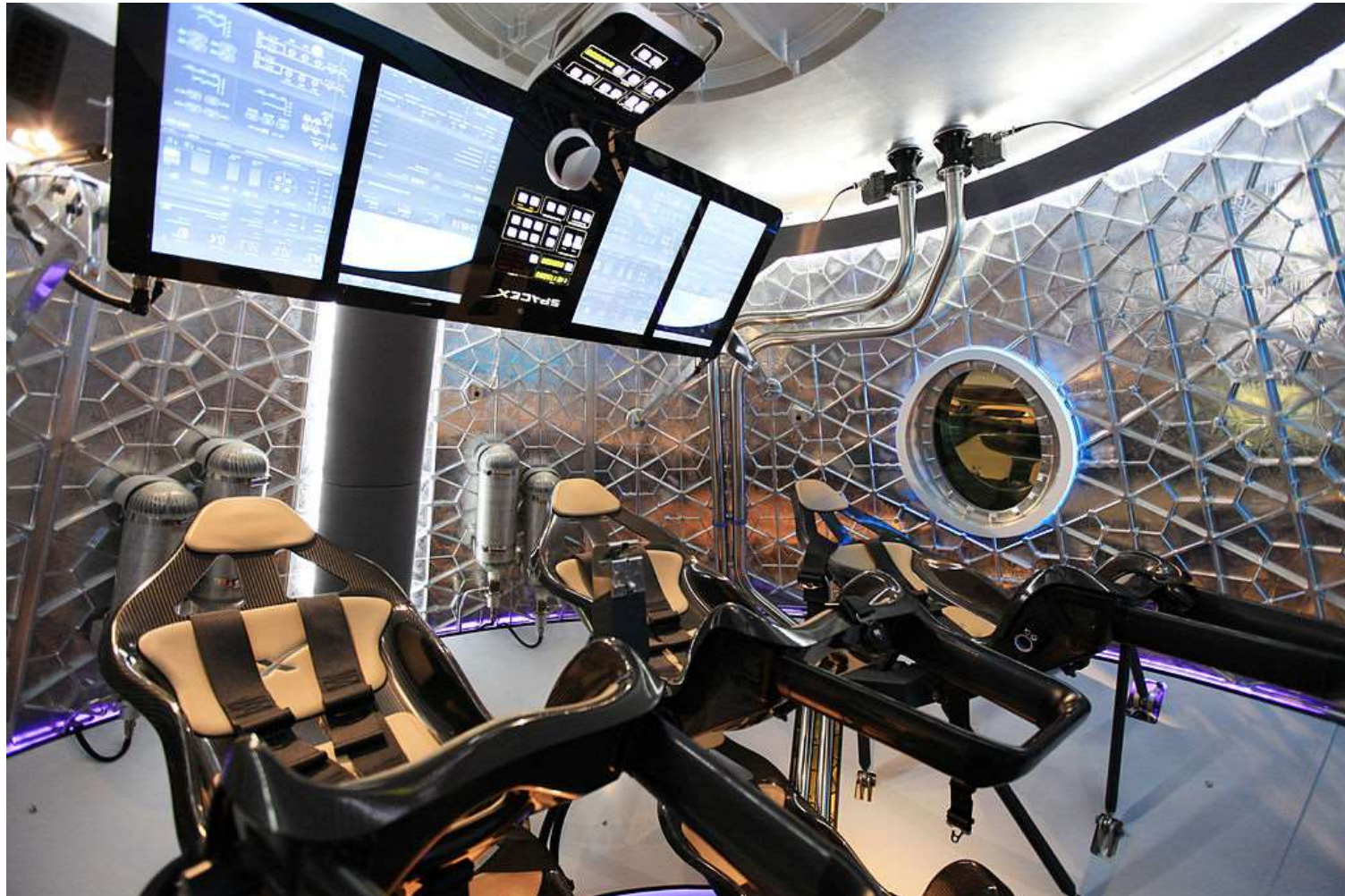


Autonomy in Human Space Flight

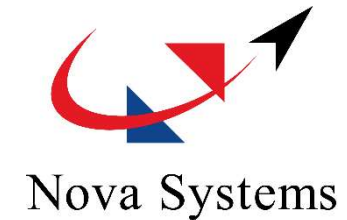


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**Space X
Dragon**



The Future – what to expect



- ✦ Potential precedents may be shaped by the fact that very wealthy people will likely be the only early space flight participants (deep pockets to sue)
- ✦ A broader pool of people with a variety of medical conditions will be extremely valuable to evaluate long term health risks of microgravity, but there will likely be surprises
- ✦ One common theme with government/commercial design approaches is that humans are acceptable backup to automated systems for fault tolerance – but is that still practical?

Questions?