Commercial Human Spaceflight Safety

By

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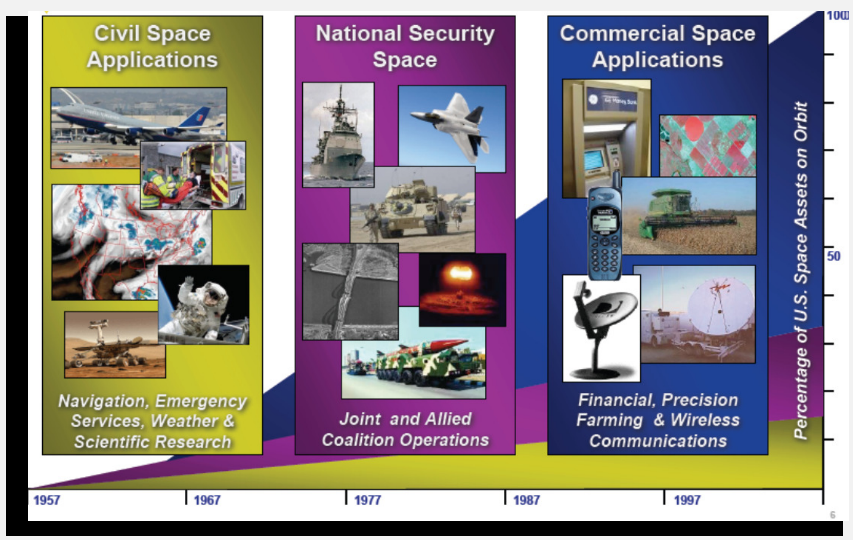
Introduction

Growing importance of commercial space

- Today, referring to all space activities as exploration activities has become meaningless. Instead space should be considered as made of two functional regions: the “**region of space-exploitation**” and the “**region of space-exploration**”. (‘exploitation’ means making productive use, while ‘exploration’ means, traveling ,over new territory, for adventure, discovery or investigation). The border between the two regions lays currently at the upper end of the geosynchronous orbits (36,000 km).

- The interests in the space-exploitation region, are mainly commercial and military, while they are scientific in the space exploration region.



A fading divide

- Several “soft” boundaries between air and space have been defined:
  - 50 Km is the upper limit of atmospheric buoyancy (balloons);
  - 80 Km is the threshold altitude that defines “astronauts” in the US;
    - **100 Km, also known as the “Karman Line”, is where aircraft aerodynamic controls become ineffective**;
    - 120 Km begins the re-entry threshold for space vehicles; and,
    - 160 Km is the lowest practical operating orbit for satellites and spacecraft.

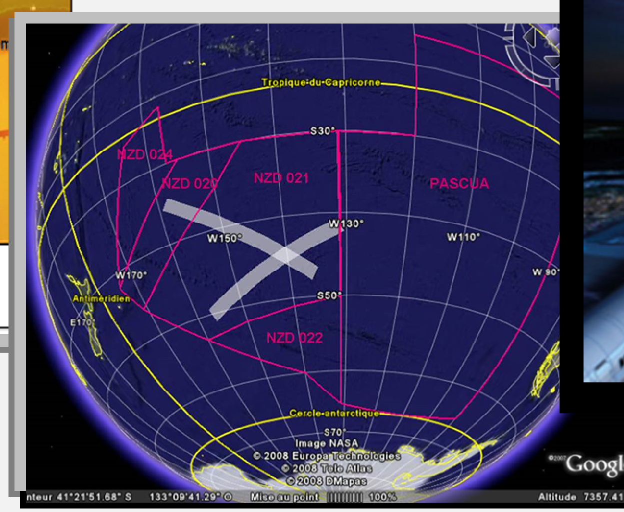
- Although the Karman-line, the 100 km separation between the field of aeronautics and that of astronautics, has been recognized for the application of national space-related regulations by some countries such as Australia, currently there **is no legally defined boundary mentioned in international aeronautical conventions and space treaties**.

A fading divide: the benefits

- Important elements of aviation infrastructure and services (**air traffic control, communication meteorology**) are becoming space-based.
- Vehicles are being developed that will **operate in both domains**.

A fading divide: the risks

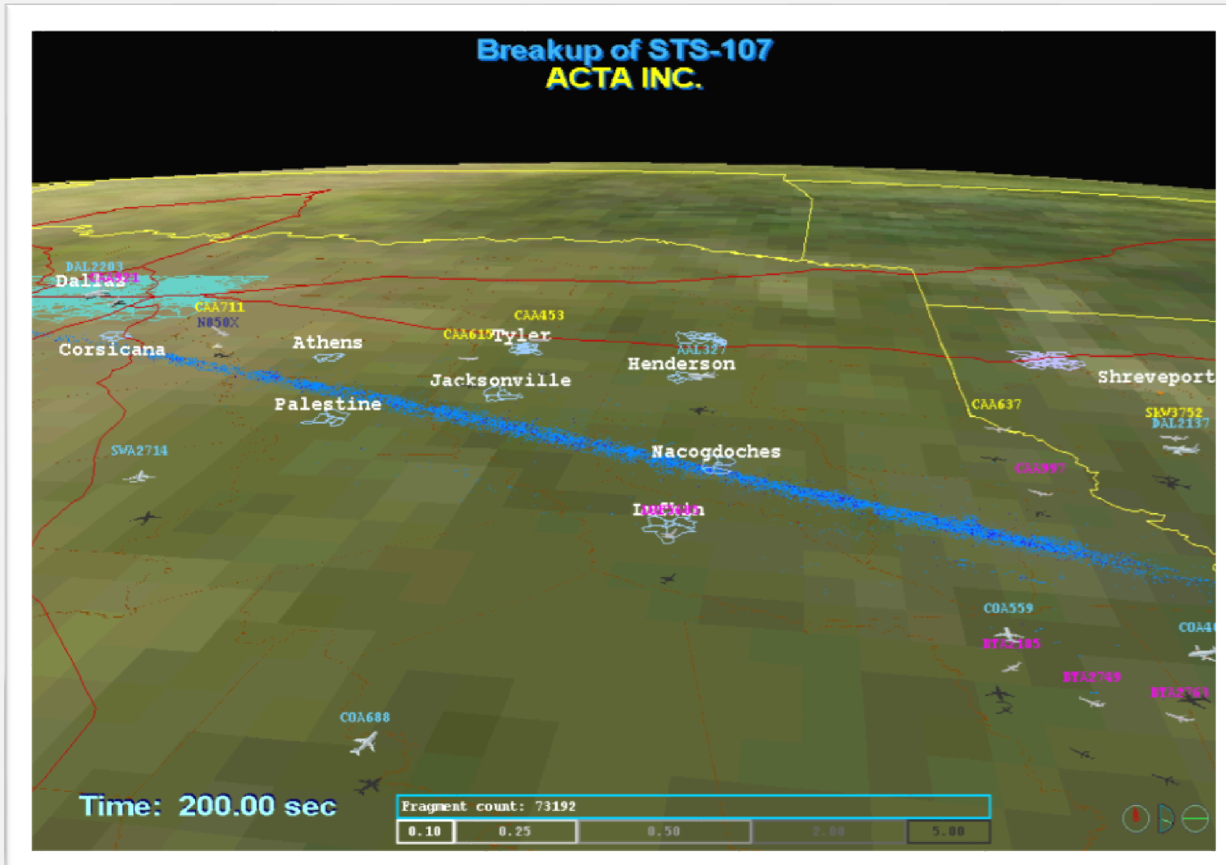
- There are common concerns like space weather, **sharing of airspace during launch and re-entry operations**, protection of the atmospheric and orbital environment (space debris).
- A large part of space launch and re-entry operations take place through the international airspace under the ICAO jurisdiction.



The Shuttle Columbia's aviation close call

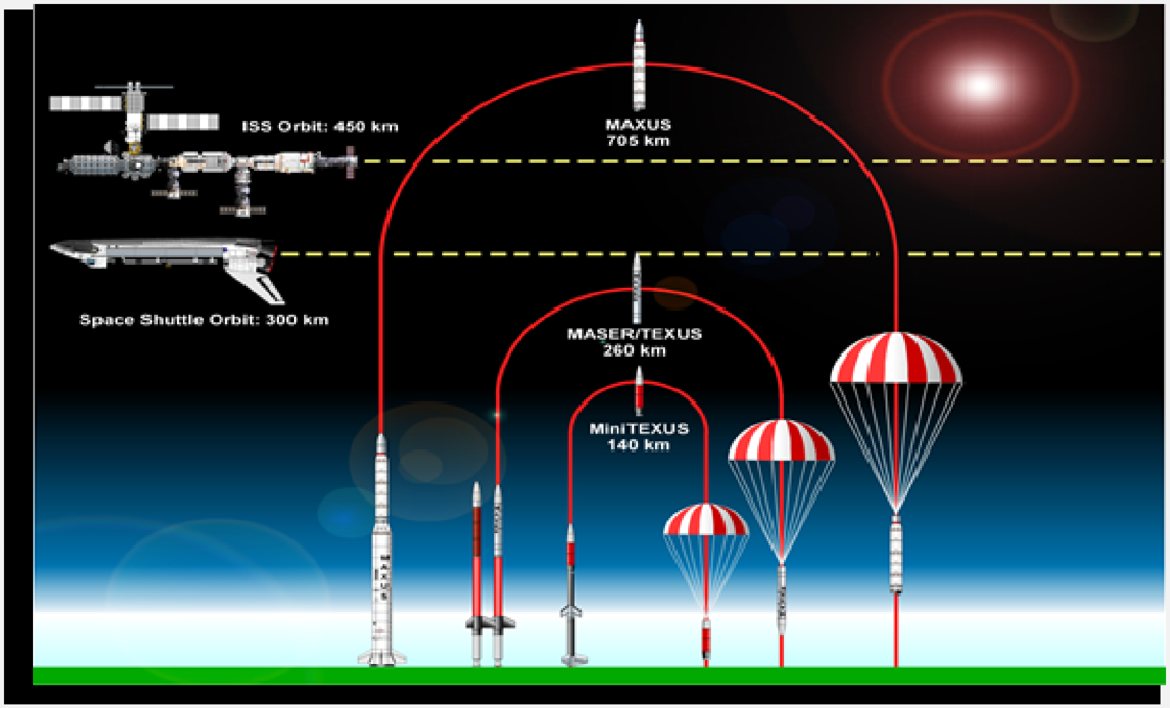
- The disintegration during re-entry of the Shuttle Columbia on February 1, 2003 was a watershed moment in the history of re-entry safety. It highlighted the need to establish preplanned **measures to keep air traffic away from falling debris** if a re-entry accident occurs.

- About 100,000 fragments were recovered for about 40% of the original weight.



Suborbital spaceflight

- Unmanned suborbital flights have been common since the very beginning of the space age. A suborbital flight is a flight beyond 100 kilometers above sea level but in which the vehicle does not attain the speed to escape Earth's gravity field (40,320 kph).



ESA unmanned suborbital rockets -credits: © ESA/G. Dechiara

First suborbital human spaceflights half century ago

- In 1961, Alan Sheppard on a suborbital flight reached **187 km** of altitude on board the first Mercury man-rated rocket (Mercury Redstone 3, a rocket with a capsule on top).

- In 1963, NASA test pilot Joseph Walker reached an altitude of **108 km** in an X-15 aircraft, and returned to the runway from which he took off (attached to a B-52 mother ship).

- The commercial human suborbital space vehicles currently in development still basically follow such configurations, plus other two consisting into an airplane with either a rocket engine or jet engine and rocket engine.

Current developments

Company: The Spaceship Company

SpaceShipTwo(SS2)	
Vehicle	Winged, hybrid rocket engine, Mach 4
Operation	- Air-launched at 15,000m by jet-powered Scaled Composites WhiteKnightTwo aircraft - horizontal landing
Mission	Sub-orbital flights, 2 pilots, 6 pax
Spaceport	Mojave Spaceport, California (USA)
Launches	2014, start of commercial operations

Safety certification authority: FAA for public launch/re-entry public safety

Company: XCOR

Lynx	
Vehicle	Winged, 4 LOX-Kerosene rocket engines , Mach 3.5
Operation	Horizontal take off and landing
Mission	- Sub-orbital flights, 1 crew, 1 pax - Small satellites orbital
Spaceport	- Mojave Spaceport, California (USA) - Caribbean Spaceport, Curacao (NL)
Launches	2014, start of commercial operations

Safety certification authority: FAA for public launch/re-entry public safety

Company: Space X

Dragon	
Vehicle	Capsule
Operation	Ground launched by Falcon 9 rocket
Payloads	- Crew (7) orbital (LEO) - Cargo
Spaceport	- Launched from Cape Canaveral Air Force Station - Splashdown landing
Tests	Drop and abort test end 2013

Safety certification authority:
- NASA for human spaceflight
- FAA for launch/re-entry

Company: Sierra Nevada & Lockheed-Martin

Dream Chaser	
Vehicle	Winged – Lifting body
Launch Operation	Ground launched by Atlas V rocket
Payloads	- Crew (2-7) orbital (LEO) - Cargo
Spaceport	- Launched from US launch range - Landing at NASA-KSC
Glide Tests	October- November 2013
Piloting	Unmanned or Manned

Safety certification authority:
- NASA for human spaceflight
- FAA for launch/re-entry

Company: Boeing & Bigelow Aerospace

CST 100	
Vehicle	Capsule
Operation	Ground launched by Atlas V rocket, (Delta IV, Falcon 9)
Payloads	- Crew (7) orbital (LEO) - Mixed crew and cargo
Spaceport	- Launched from LC 41, Cape Canaveral Air Force Station - Splashdown landing
Tests	Subsystems test on going

Safety certification authority:
- NASA for human spaceflight
- FAA for launch/re-entry

Company: Blue Origin

New Shepard	
Vehicle	- Capsule powered by High Test Peroxide (HTP) and RP-1 kerosene. - Propulsion Module, with reusable liquid oxygen, liquid hydrogen rocket engines
Operation	- Ground launched by rocket-powered Propulsion Module - Propulsion Module lands vertically (VTVL) - Capsule lands with parachute
Payloads	Crew (3) suborbital
Spaceport	- Launched from LC 39A, Cape Canaveral Air Force Station
Tests	Launch, landing and escape systems tests performed in 2012

Safety certification authority: FAA
for public launch/re-entry public safety

Company: Reaction Engines

Skylon	
Vehicle	Winged, 2 SABRE engines mix hydrogen jet and LOX-hydrogen rocket engine, Mach 5,4 as jet
Operation	Single-stage-to-orbit, horizontal take off and landing
Mission	- Orbital & sub-orbital flights, - Small satellites orbital
Airport	TBD
Tests	Flight tests 2020

Safety certification authority: UK CAA

Company: Swiss Space Systems

Swiss Space System (S3)	
Vehicle	Winged – lifting body
Operation	Air launched from Airbus A300
Mission	- Sub-orbital Intercontinental flights - Small Satellites Orbital
Airport	- Payerne Airport (CH) - Malaysia - Morocco
Tests	Flight tests 2017

Safety certification authority: EASA (TBC)

Company: EADS - Astrium

Vinci Spaceplane	
Vehicle	Winged, Mach 3, 20 tons Double propulsion: jet engines, cryogenic methane/oxygen rocket engine
Operation	Horizontal take off and landing
Mission	- Sub-orbital manned, 6 pax, 2 crew - Small satellites launch
Airport	TBD
Development Status	Studies

Safety certification authority: EASA

Company: Dassault

VSH	
Vehicle	Winged – lifting body, Mach 3.5 Propulsion Lox/Kero, 11 tons
Launch Operation	- Air launched - Horizontal landing
Mission	Sub-orbital manned, 6 pax
Airport	TBD
Developmen t Status	Studies

Safety certification authority: EASA
(as a high performance aircraft)

Company: Copenhagen Suborbital

TychoDeepSpace II	
Vehicle	Capsule
Launch Operation	Sea launched by HEAT 1600 rocket
Payloads	Sub-orbital
Spaceport	TBD
Development Tests	On-going, including tests of the escape system

Safety certification authority: TBD

Safety

Historical safety records

- **Capsule configuration** - The available (statistically significant) safety record for capsule configuration is that of Russian Soyuz (orbital vehicle). As of beginning of 2013 there have been 115 manned Soyuz launches with 4 failures in total: 2 during launch with no casualty (thanks to the activation of the abort systems), and 2 at re-entry with 3 casualties in total.

- **Air-launched configuration** – On a total of 199 flights X-15 flights there were 1 engine failure and 1 engine explosion with damages at landing (no casualty), and 1 crash with 1 casualty.

Suborbital spaceflight safety target

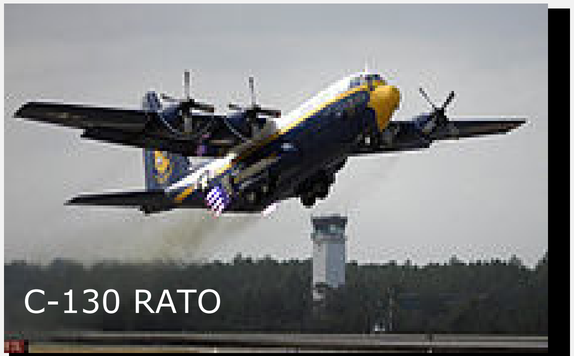
- The IAASS considers that a quantitative safety target of **1 accident per 10,000 flights** may be achievable in current suborbital vehicle developments by using proven, well understood and reliable rocket propulsion technologies, application of best safety practices from past and current aeronautical and space projects, performance of wide ground and flight testing program, and rigorous quality control program.

Suborbital vehicles top-risks

Design	Capsule	Air launche	Rocket propulsio	Winged system
Carrier malfunction		X		
Explosion			X	
Launcher malfunction	X			
Inadvertent release or firing		X		
Loss of pressurization	X			X
Loss of control at reentry				X
Parachute system failure	X			
Crash landing				X
Escape system f...	X			
Falling fragments (catastrophic failure)				X
Leaving segregated airspace	X			X
Atmospheric pollution			X	

It is a rocket or an airplane?

A space vehicle needs rocket propulsion to travel in vacuum. But a vehicle like a car or an airplane which uses rocket propulsion to accelerate on ground or in air is not a space vehicle! Since WWII there have been several types of (military) planes that have made use of rockets during take-off (RATO).


C-130 RATO

Parabolic flight

A person on a space vehicle orbiting Earth will experience weightlessness, but you can experience **weightlessness** also on a free fall or **on an aircraft performing a parabola**. Space agencies usually use aircraft parabolic flights to test equipment and train astronauts.

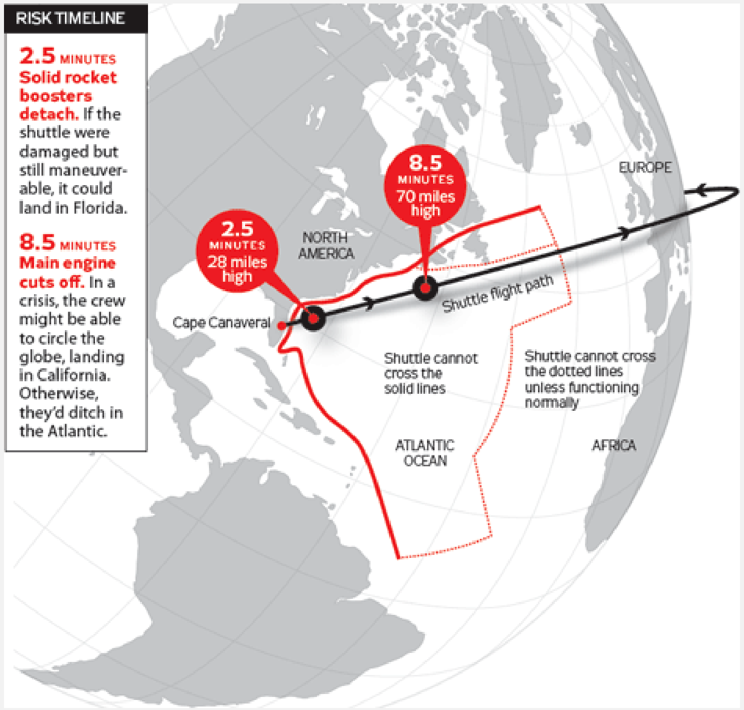
Most commercial human suborbital systems currently in development are **essentially high-performance aircraft that use rocket propulsion to accelerate in air** (rocket burn-out around an altitude of 60 km) while **in a parabolic flight**.

Airspace safety considerations

- Rocket powered unmanned and manned systems (see Shuttle) traditionally include a destructive FTS to prevent departure from segregated airspace or flight path in case of malfunctioning. The suborbital winged systems currently in development do not include a FTS. Furthermore, under US law, there are no regulations levied for the safety of passengers and crew, but only for the protection of the uninvolved, public.

- **It is IAASS recommendation that "unregulated" suborbital human spaceflight should be treated according to the same safety rationale being adopted for allowing civil UAVs in the airspace** (i.e. a number of safety requirements apply in any case).

- In addition, any original aeronautical certification of equipment and systems should be considered invalid due to exposure to vacuum (e,g, jet engines)



Conclusions: The time to organize space is now!

- Adopt the International Code of Conduct for Space Operations, but separate military Space Situational Awareness (SSA) issues from civil/commercial Space Traffic Management (STM). Define borders and interfaces between military SSA and civil/commercial STM.

- Enlarge national launch authorities mandates (e.g. FAA-AST) to include commercial on-orbit space operations licensing, and civil/commercial STM services.

- Work with ICAO to Integrate Air Traffic Management and Space Traffic Management in a single international system

- Launch inter-government cooperation for creating international voluntary space safety standards.

Acknowledgments

This presentation is based to a large extend on the results of the IAASS Study Working Group **"An ICAO for Space?''** I co-chaired with Prof. Ram Jakhu of the McGill University, Institute of Air and Space Law.

The complete results of the IAASS study are collected in the book **" The Need for an Integrated Regulatory Regime for Aviation and Space"** sponsored by ESPI (European Space Policy Institute), co-edited by R. Jakhu, T. Sgobba and P. Dempsey, and published by Springer in 2011.

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