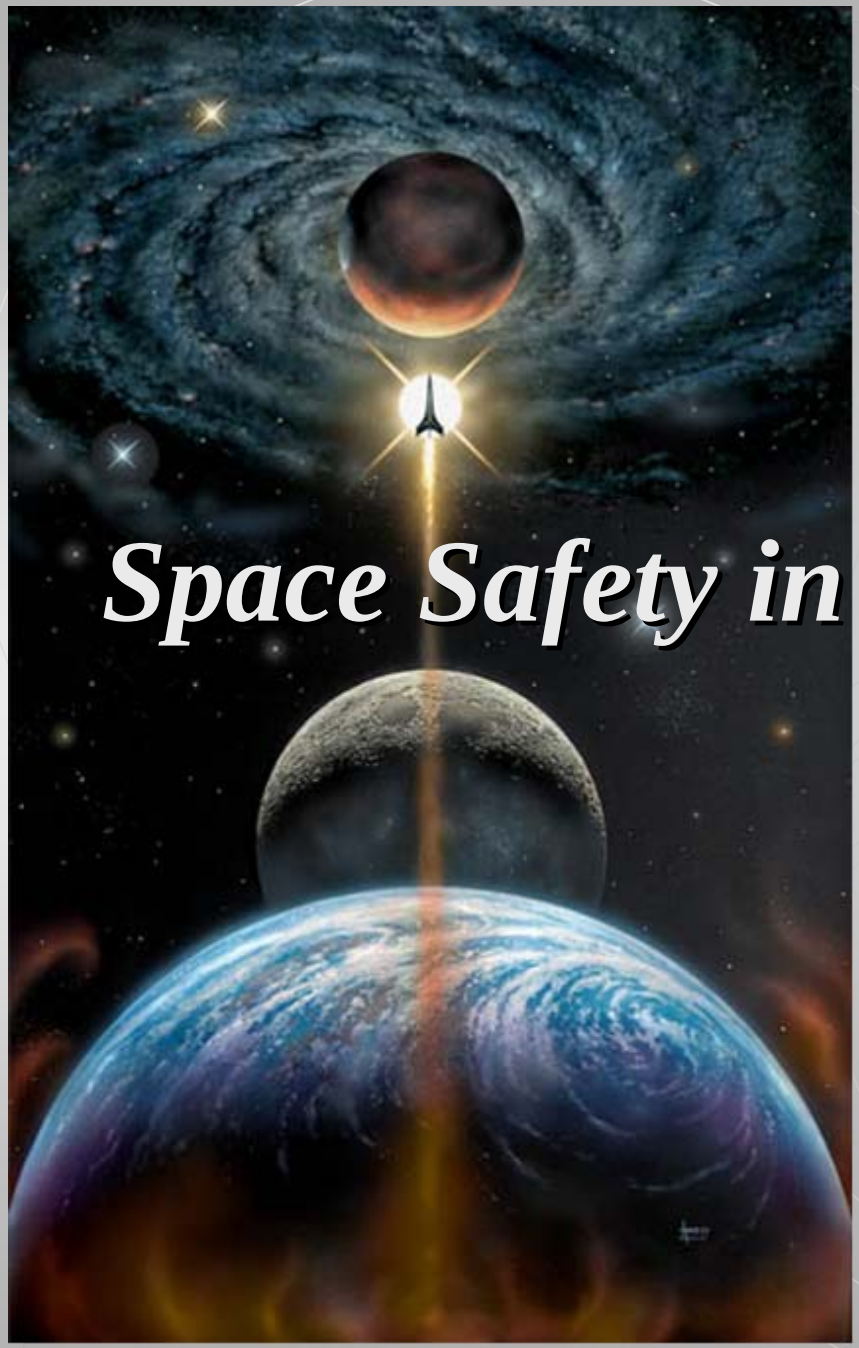


"Over the long run the safety of all human beings in the global commons of space is a responsibility that must be shared by all space-faring powers"

G. Rodney, NASA Associated Administrator S&MA
40th IAF Congress, October 1989, Beijing - China

Space Safety in a Global World

By

T. SGOBBA

IAASS President

What is Space Safety?

Safety Risk of Space Missions (accidents)

- As of today (at least) 200 people have been killed on ground by rocket explosions during processing, launch preparations and launch. Since the year 2000, 35 casualties were counted (last accident in July 2007)
- In the last 10 years at least 6 launches were terminated by launch range safety officer to prevent risk for the public. Several more cases of launchers which did not make to orbit and crushed back on Earth
- A total of 22 astronauts and cosmonauts have lost their lives since the beginning of human spaceflight. Four of which on ground during training, (one Russian, plus the Apollo 1 crew). About 4% of those who flew, died
- The Shuttle Columbia accident posed a serious risk to civil aviation (in the order of 1/1000 for commercial airlines and 1/100 for general aviation)
- A Proton launcher failure in September 2007 contaminated a vast swath of agricultural land of Kazakhstan with 200 tons of toxic fuel

Safety Risk of Space Missions (accidents)

Source book: *Satellites*

Safety Risk of Space Missions (orbital debris)

- Risk represented by orbital debris, including about 200 “dead” spacecraft abandoned in orbit, and the risk of uncontrolled spacecraft re-entry.
- Currently 9,000 orbiting objects are being tracked, while more than 100,000 bits of debris are too small to follow. Some debris will remain in orbit for hundreds or thousands of years and constitute a potential catastrophic hazard for operational spacecraft because the high relative velocities at impact.
- Debris impacts on the Shuttle are counted on every mission. The second largest hit was the perforation of a thermal radiator during the STS-115 mission in September 2006. It could have killed on the spot an astronaut performing extra-vehicular activities (EVA)
- Collision with orbital debris is the primary safety risk for the International Space Station

Safety Risk of Space Missions (orbital debris - cont'd)

- The ASAT (anti-satellite test) performed by China in January 2007 was the second-ranking fragmentation event in space history. The test caused an increase of collision risk for many satellites. For the International Space Station (ISS) the risk increased of nearly 60% for fragment > 1cm.
- To reduce the space debris risk, satellites should be disposed, in accordance with UN guidelines, at the end of their operational life by either de-orbiting (those in LEO) or moving to "graveyard" orbits (those in GEO).
- It can be expected that such (mitigation) guidelines will not be uniformly followed world wide as long as there is no national or international obligation to do so. In particular there is no obligation to remove failed satellites
- In February 2008, the US Navy shot down with a missile a malfunctioning intelligence satellite, allegedly because of the risk for ground population of ½ ton of toxic fuel on board (in the process a number of orbital debris were created)

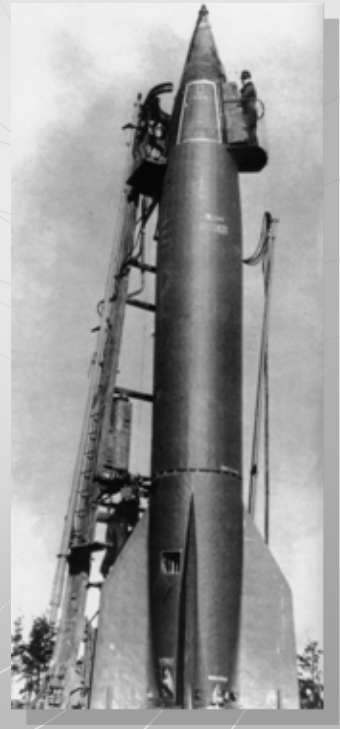
Safety Risk of Space Missions (cont'd) (radioactive risk)

- As of today there have been 10 cases of failures leading to dispersal of radioactive material, including:
  - plutonium payload on board Apollo 13 lunar module which ended up in the Pacific Ocean close to the coast of New Zealand, or
  - 68 pounds of uranium-235 from the Russian Cosmos 954 which were spread over Canada's Northwest Territories in 1978;
  - most recent accident of this kind in 1996, when the Russian MARS96 disintegrated over Chile releasing its plutonium payload which has never been found.
- Currently there are 32 defunct nuclear reactors, 13 reactor fuel cores and at least eight radio-thermal generators (RTGs) circling Earth. The total mass of RTG nuclear fuel is about 150kg, while there are 1,000kg of radioactive fuel from nuclear reactors.

The military cultural heritage = mission as # 1

The military heritage: mission first

- The **Space Age** started in Wassenaar (NL), around the corner from my house, with the launch of the first V2 Rocket at 18.37 hr. on September 8 1944.



The military heritage: mission first (cont'd)

- Soviet Air Force Major Yuri Alekseevich Gagarin, 27. First man to orbit the Earth, on April 12, 1961


The Huntsville Times
Man Enters Space
'So Close, Yet So Far,' Sighs Cape
U.S. Had Hoped For Own Launch
Soviet Officer Orbits Globe In 5-Ton Ship
Maximum Height Reached Reported As 188 Miles
Hobbs Admits 1944 Slaying
Praise Is Heaped On Major Gagarin
To Keep Up, U.S.A. Must Run Like Hell'
Reds Deny Spacemen Were Died
ning Lead In Race To Control Space

The military heritage: mission first (cont'd)

- For more than half a century launchers have been developed as a "dual" technology primarily oriented toward military purposes
- Manned spaceflight started during the Cold War and has been mainly a political tool evolving in synchronous with the (two) superpowers relationship. Initially as Cold War technological supremacy propaganda tool, later as a tangible sign of goodwill and mutual acceptance of the "status quo". Finally after the collapse of the USRR as means to prevent a feared "migration" of technical skills (toward rogue states)
- As a consequence of the original military/political imprint space programs have been very much **mission driven**. Safety has been a subordinate or implied objective and second to costs in driving the conceptual design.

The way it was (cont'd)

- In the case of the Shuttle the **primary mission** was that of cutting by something like an order of magnitude the cost of transportation to orbit (which failed)

- Eventually (as for ***Concorde***) it was doomed by being **expensive to operate and unsafe**. (Being expensive made in turn unaffordable any substantial safety modifications)

No regulations and one man in charge

- Most **space programs** being government programs they have been basically **unregulated** (nationally and internationally)

- The initial space programs required men of exceptional intellectual and managerial skills with access to **unlimited resources**

Von Braun

Korolev

- Later the space **Program Managers** have continued to be the **single source of decisional power** for all aspects of system design and operations including safety (**but within strict budgets constraints**).

The New Space Age

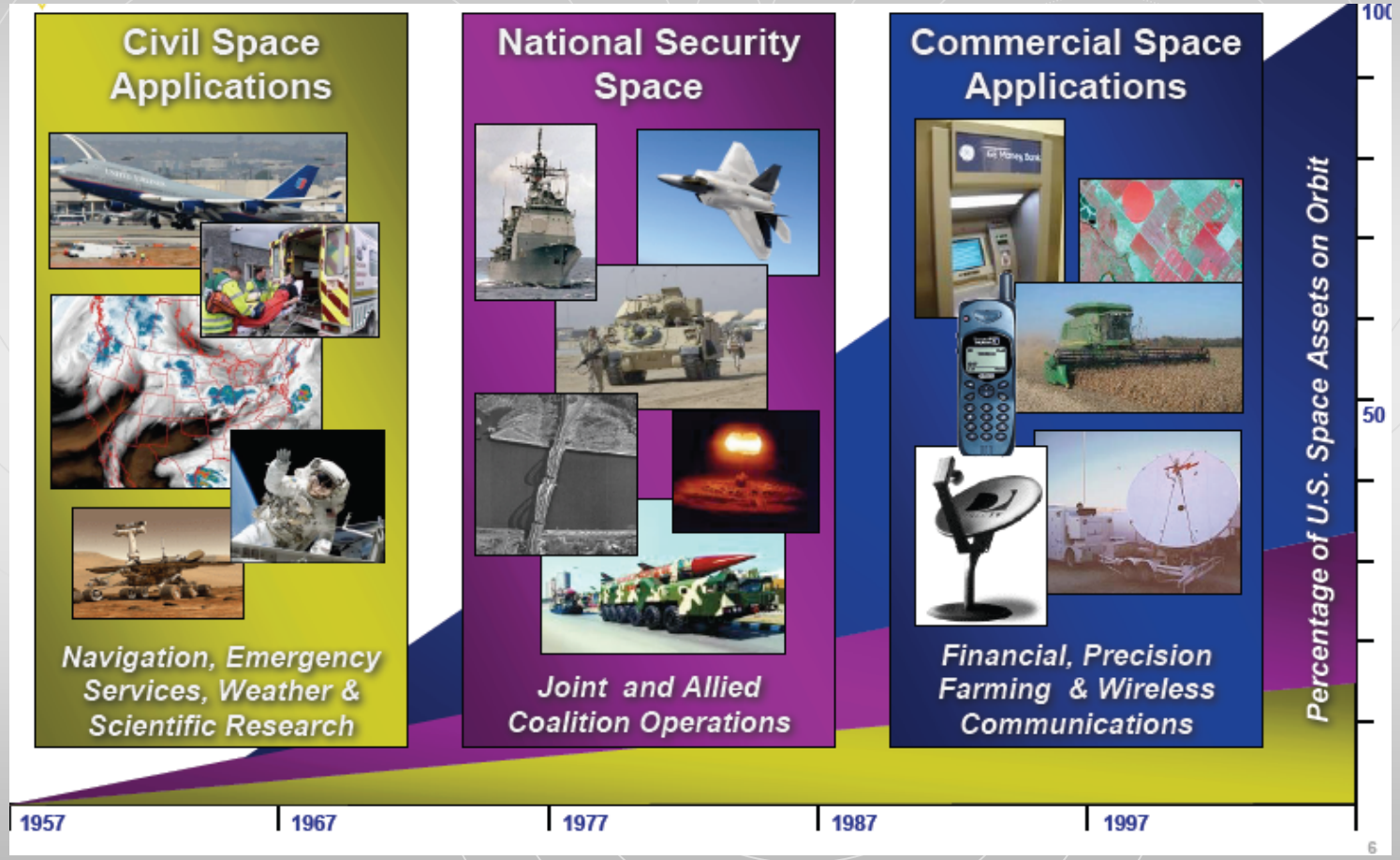
The New Space Age

- By the end of the end of the 1990's the importance of the commercial space revolution and the merging of several technologies, was already very clear:

"…This revolution is increasingly blurring the traditional distinction between things military and commercial, between things private and governmental, and things domestic and international. We are dealing with a new set of historical conditions, many of them unprecedented. Therefore, we must resist the temptation to apply models or adopt solutions that were more appropriate to the past, or to entirely different historical or economic circumstances without first understanding the implications for the future…This New Space Age or era of "New Space" differs dramatically from the era we have just left in significant ways. First, it is increasingly privately funded and commercial in nature. Second, it will be predominantly international, blurring the once clear lines between what is "ours" and what is "theirs."

(K. Calhoun-Senghor, Director of the Office of Space Commercialization, U.S. Department of Commerce, before the House Subcommittee on Space & Aeronautics - March 1999).

The New Space Age



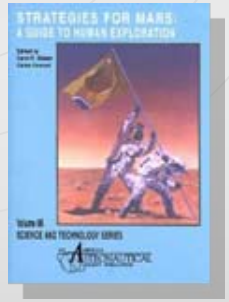
Source: J. Squatrito – CDI Conference -London 25 October, 2007

The turning point: 2002-2004

Cluster of accidents

Raising of new space-powers

Exploration program launch



Raising of commercial space

NASA Commercial Crew/Cargo Project

The Space Safety Global Dimension

Global Aspects of Space Safety

- Public acceptance of space missions safety risk
- Future international human spaceflight programs
- International dimension of launch & re-entry risk
- Safe use of Nuclear Power Sources
- Enabling space commercialisation
- Protection of space assets

Acceptable space safety risk

- A Shuttle launch as any human spaceflight event receives a worldwide media attention which foster a global awareness and attention for space safety risk
- The greatness (and high cost) of such endeavours makes the public less tolerant to failures, in particular those failures which are perceived as preventable or within the reach of current knowledge
- Realising (ground and flight) safety levels in space programs which better match public expectations is fundamental for the expansion (and sometimes even continuation) of government and private spaceflight programs worldwide
- The level of risk of very complex space systems is embedded in the architecture and operations concept originally selected. **Safety must be designed-in** by:

  a) making safety the center of the conceptual design efforts, and
  b) raising the entire design team awareness of hazards & mitigations means

Future international human spaceflight

International cooperation in human spaceflight programs will represent more and more the norm in future. Future programs require:

- Mastering new/advanced technologies for hazards control (e.g. dust, radiation, etc.)
- Consistent/"auditable" safety organisation elements, and effective single safety authority (ISS lesson learned) for multinational programs
- Creation of an international (technical) safety culture. In other words a common understanding about what it is safe and what is unsafe (absolute safety does not exists!)
- Interoperability standards to allow for mutual aid during emergencies

An international space safety culture

Which water we will carry to Mars?

An international space safety culture

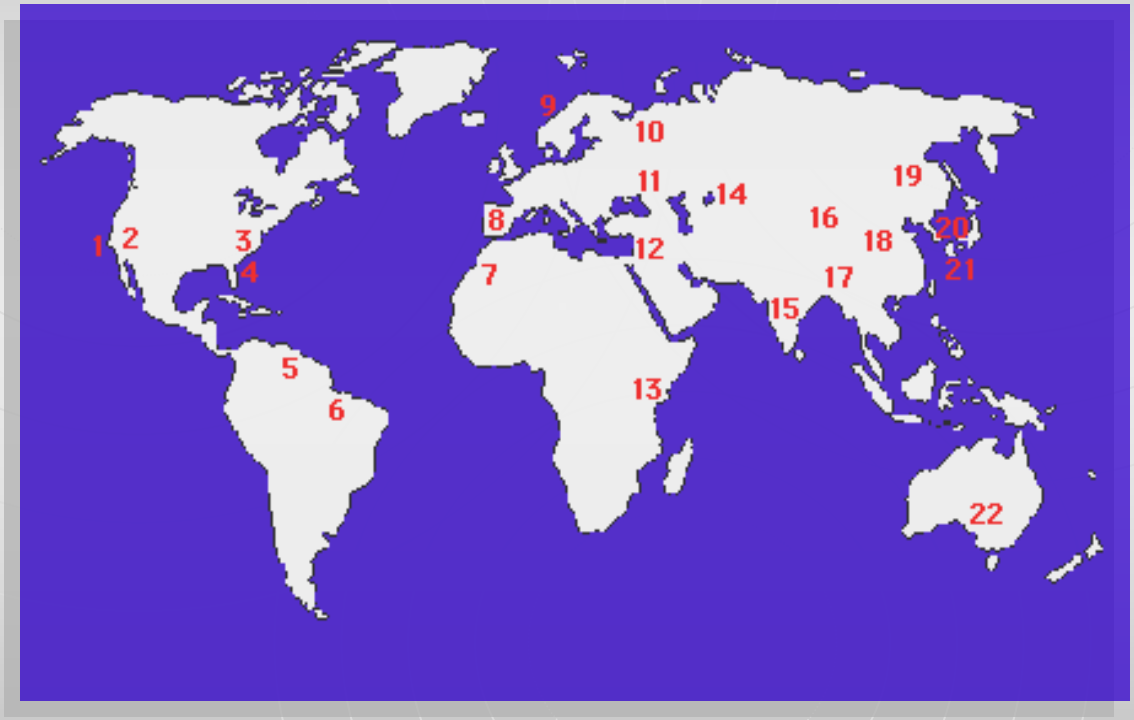
Traditional individual, corporate and national cultural differences can increase the safety risk. Differences need to be understood, compared, discussed and as necessary modified through consensus, training, new standards and regulations. Examples:

- Individual attitudes (e.g. jealous ownership of technical knowledge)
- Conflicting experience-based technical requirements (e.g. ISS water/air)
- Government regulations (e.g. export control, ITAR)
- Different product-safety cultures (i.e. prevention of misuse vs. correct instructions for use)
- Mixed crews interactions/psychology on long duration operations.

International dimension of launch & re-entry risk

- Rising number of countries with independent access to space
- Non uniform launch safety record worldwide
- Lack of uniform international risk acceptance criteria
- International nature of spaceports operations (foreign teams on-site)
- Risk overlapping from different launch sites not accounted for
- Case-by-case & country-by-country management of airspace interfaces
- Commercial pressure to make safety standards less stringent
- Environmental issues of air/ground/water contamination
- Re-location of some launchers from their original launch sites
- Overall issue of uncontrolled spacecraft re-entries

International dimension of launch & re-entry risk



Launch Sites Worldwide

Safe use of Nuclear Power Sources

- Interplanetary exploration missions (automatic and human) require use of Nuclear Power Sources (NPS)
- Technical requirements and safety certification processes currently in place only in US (Russia ?)
- On-going studies and activities in ESA/EU to establish an international safety framework for European missions
- International regulations are long overdue

Enabling space commercialisation

- A framework of international safety regulations, and an international regulatory body are needed to enable private spaceflight and other transportation services to orbital space stations

Suborbital Space Tourism

- The first suborbital vehicles are being built by an American company (Scaled Composites) but will be owned and operated by a UK company, Virgin Galactic. According to the Outer Space Treaty both countries are liable and shall issue licenses. FAA will certify the vehicle public safety (only) against US regulations. Virgin Galactic has contacted the UK's British National Space Centre (BNSC), which is involved in the UK's launch licensing process, about its plans. BNSC is to conduct a consultation with human spaceflight stakeholders in the coming months and plans to involve the UK's Civil Aviation Authority, which has previously been responsible for giving permission for UK rocket launches due to issues of notification for pilots and airlines.

- Suborbital flights spaceports are being evaluated in US, Singapore, Dubai, Malaysia, UK and Sweden. Lack of a standard framework of international safety regulations will hamper space-tourism.

Commercial human orbital flights

- Orbital space tourism became reality in April 2001, through the use of Russian government vehicles and related infrastructure. The first space tourist, the American businessman Dennis Tito was launched on a Russian *Soyuz* spacecraft, which docked with the International Space Station (ISS).

- Orbital space tourism with use of private vehicles and on-orbit and ground infrastructure, will require the establishment of dedicated regulations nationally and internationally, in particular to make provision for abort/alternate/emergency landing on foreign soil.

[Note: Shuttle foreign landing sites include: a) Launch Abort Sites: Halifax, Stephenville, St Johns, Gander, Goose Bay (all in Canada); b) Augmented Landing Sites: Zaragoza and Moron in Spain, Istres in France, Ben Guenir in Morocco, Banjul in Gambia and Dakar in Senegal; c) Emergency Landing Sites: 18 foreign sites from Germany to Sweden, Turkey, Australia and Polynesia]

Commercial orbital transportation services

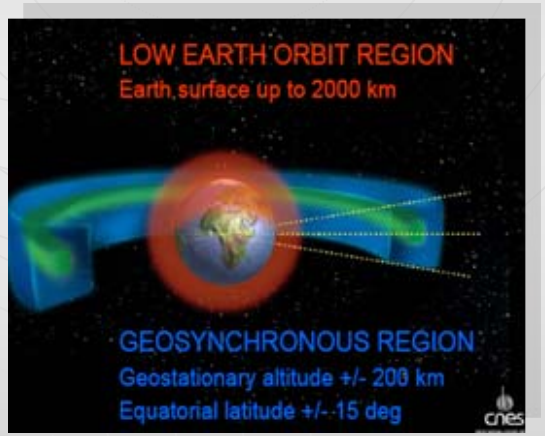
- NASA's ***Commercial Orbital Transportation Services*** (COTS) program will contract with one or more space transport firms to deliver a given amount of cargo to the International Space Station each year. Eventually this would also include delivery and return of crew members to and from the ISS as well.

- NASA will not specify the design of the launch systems. The agency will just examine the proposed system to insure that it is a reasonable design and is compatible with the ISS operations.

- The COTS vehicles design and operations for launch and re-entry will be safety certified by FAA-AST. They should be also certified against commonly agreed standards by delegates of ISS Government signatories, for all those design and operations aspects which directly or indirectly affect the safety of ISS during the rendezvous, docking and attached phases. Such standards may well be the seeds of future international civil space standards

Protection of on-orbit space assets

- Today man-made orbital debris poses a risk to both manned and un-manned spacecraft. They include about 200 spacecraft abandoned in GEO orbits
- The in-orbit debris population is growing and probability of damaging collisions is increasing
- Voluntary mitigation measures to preserve the LEO and GEO space environment for future generations have been agreed by main space agencies



- A framework of international enforceable regulations is needed

Are current rules adequate?

Space Law: many principles, no rules (cont'd)

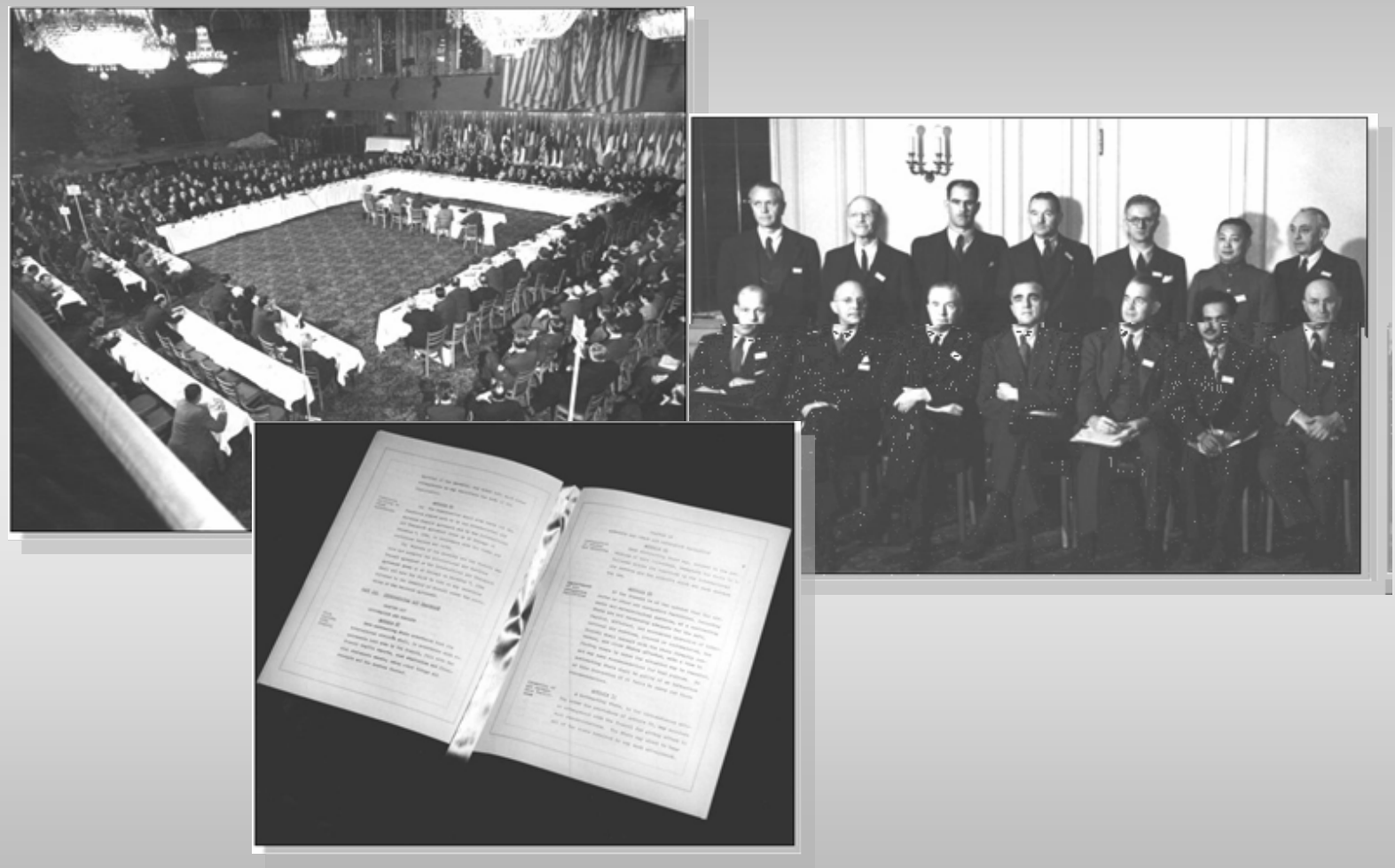
- Space treaties provide generic principles but no implementing rules.
- Produced at a time in which U.S. and Soviet Union, locked in the Cold-War atmosphere, had (**government**) monopoly on space activities
- Conceived for the purpose of **defining the overall limits** applicable to each nation space activities and not to facilitate and promote international cooperation and commerce in space
- During the negotiation of the Outer Space Treaty, the Russians even proposed a text which prohibited private activities in space. The negotiation on this point eventually lead to allowing private activities but (differently from maritime and air law) making the countries 'responsible' and 'liable' for the space activities of their nationals (person, companies etc.), but **without defining common public safety standards**

Which way ahead?

The New Space Age Requires a New Order

- Commercial and military space-based systems are nowadays synergetic with the systems on Earth and essential to human activities.
- The fallacy and limits of voluntarism and counting on good intentions is apparent, as demonstrated by the vain attempts to limit proliferation of space debris (a primary threat for manned and unmanned systems).
- Space up to and including geostationary orbits has become as international sea waters and airspace another realm where it is in the interest of the global community to operate in accordance with clear international rules instead of vague principles.
- An international regulatory framework is needed. The best solution would be to extend to “near-space” the ICAO convention

What is ICAO?



ICAO Convention – Chicago, December 1944

What is ICAO?
(International Civil Aviation Organisation)

- The U.S. initiated in 1943 studies of post-war civil aviation, which confirmed that civil aviation had to be organized on an international scale to become a key element of the world economic development.
- At the end of 1944, the U.S. invited 55 states to attend an International Civil Aviation Conference in Chicago.
- The Convention on International Civil Aviation was signed on 7 December 1944. The 96 articles of the Convention established the adoption of International Standards and Recommended Practices (SARPs) to secure the highest possible degree of uniformity in regulations and standards, procedures and organisation regarding civil aviation matters.
- The Convention set up the permanent International Civil Aviation Organisation (ICAO). In 1947 ICAO became a UN specialised agency.

Extending ICAO to Space

Extending ICAO Mandate to Space (rationale # 1 – Integrated Traffic Management)

- Major spaceports and launch sites are generally located close to the ocean coastline. In some cases launches take even place directly from ocean platforms. Spacecraft re-entry trajectories are selected as much as possible with similar criteria, and all controlled destructive re-entries are all aimed to the oceans. Because national airspace extends only 12 miles from coastline, most of current launch and re-entry activities take place through the international airspace controlled by ICAO.

- As aviation and space traffic continue to grow, ICAO has an increasing primary responsibility and duty of promoting innovative strategies to ensure the safety of the “integrated” air and space traffic in the international airspace, which is where those traffics mostly interact.

Extending ICAO Mandate to Space (rationale # 2 – Space Based Aviation Critical Services)

- In the near future a number of critical aviation systems, from traffic control to high resolution weather forecasts and digital aviation communications will be based in space. This means that aviation safety will mainly depend from the integrity and reliability of space based systems and services. Assigning the international coordination and control of the "near-space" to ICAO, instead of a separate international space organisation, would bring about obvious advantages in terms of synergies and efficiency.

Extending ICAO Mandate to Space (rationale # 3 – Hybrid Systems)

- The already started trend to develop and operate hybrid systems (i.e. aero-spacecraft) from dual ground infrastructure (airport/spaceports), requires a well integrated international regulatory framework both for flightworthiness certification and ground operations, which a single organisation (i.e. ICAO) would achieve more efficiently than by separate international space and aviation organisations.

IAASS
Rome Manifesto for a Safe & Sustainable Space

- *Ensure that citizens of all nations are equally protected from the risks posed by launching, over-flying, and re-entering/returning of space systems;*
- *Ensure that all space systems are designed, developed, built and operated in accordance with common minimum ground and flight safety rules, procedures and standards based on the status of knowledge and the accumulated experience of all space-faring nations;*
- *Establish international traffic control rules and management for launch, on-orbit and re-entry operations to prevent collisions or interference with other aerospace systems and with air traffic and air navigation systems;*
- *Ensure the protection of the ground, air and on-orbit environments from chemical, radioactive and debris contamination related to space operations;*
- *Ban intentional destruction of any on-orbit space system or other harmful activities that pose safety and environmental risks;*
- *Ensure that mutual aid provisions for emergencies involving space mission safety emergencies are progressively agreed, developed, implemented and made accessible without discrimination or restriction anywhere on the Earth and in Outer Space.*