Space Safety and Space Traffic Management

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Some basic facts and trends

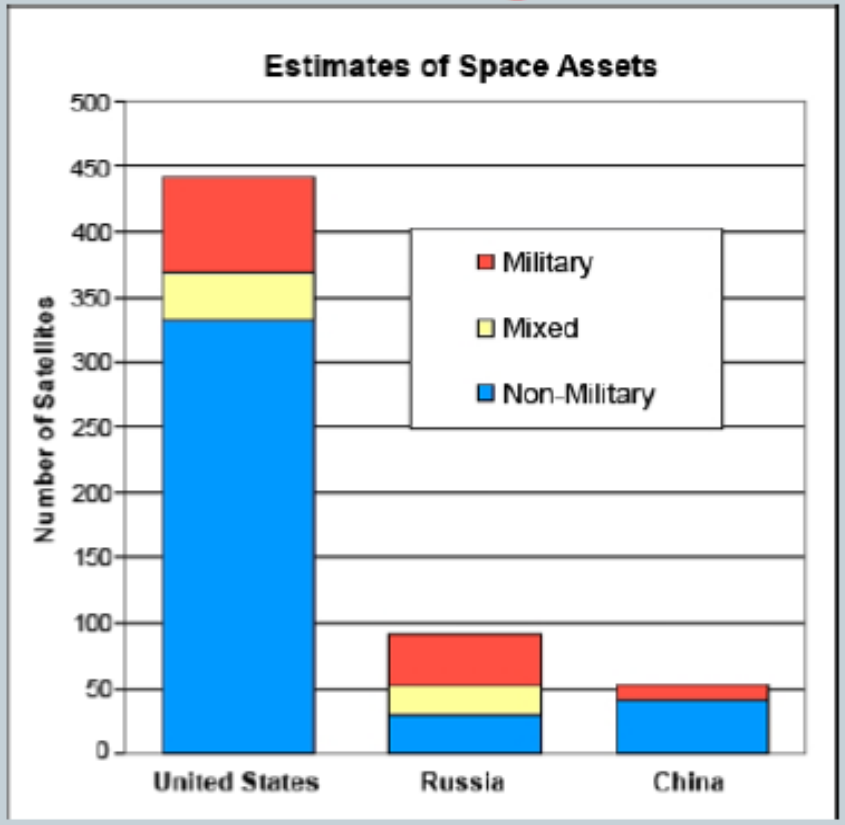
UCS: Satellite Quick Facts
(launches through 31 January 2015)

Total number of operating satellites: 1,265

US: 528	Russia: 131	China: 132	Other: 474

LEO: 669	MEO: 94	Elliptical: 37	GEO: 465

Private sector already operates more satellites than governments



Courtesy McGill Univ.

Signs of an upcoming satellite internet "Gold Rush"

- Canada: CANPOL-2 up to 72 satellites in different orbits & in VHF-, UHF-, X- & Ka-band
- Canada: COMSTELLATION, 794 satellites in LEO in Ka-band
- France: Thales Group's MCSat, between 800 & 4,000 satellites in different orbits & in Ku- & Ka-band
- Liechtenstein: 3ECOM-1, 264 satellites using Ku- & Ka-band
- Norway: ASK-1, 10 satellites in elliptical orbit in X-, Ku-, Ka-band
- Norway: STEAM-1, 4,257 satellites in Ku-band
- US: OneWeb to build a 650-satellite constellation
- US: SpaceX to build a 4,000-satellite constellation

Courtesy McGill Univ.

STM and Space Safety

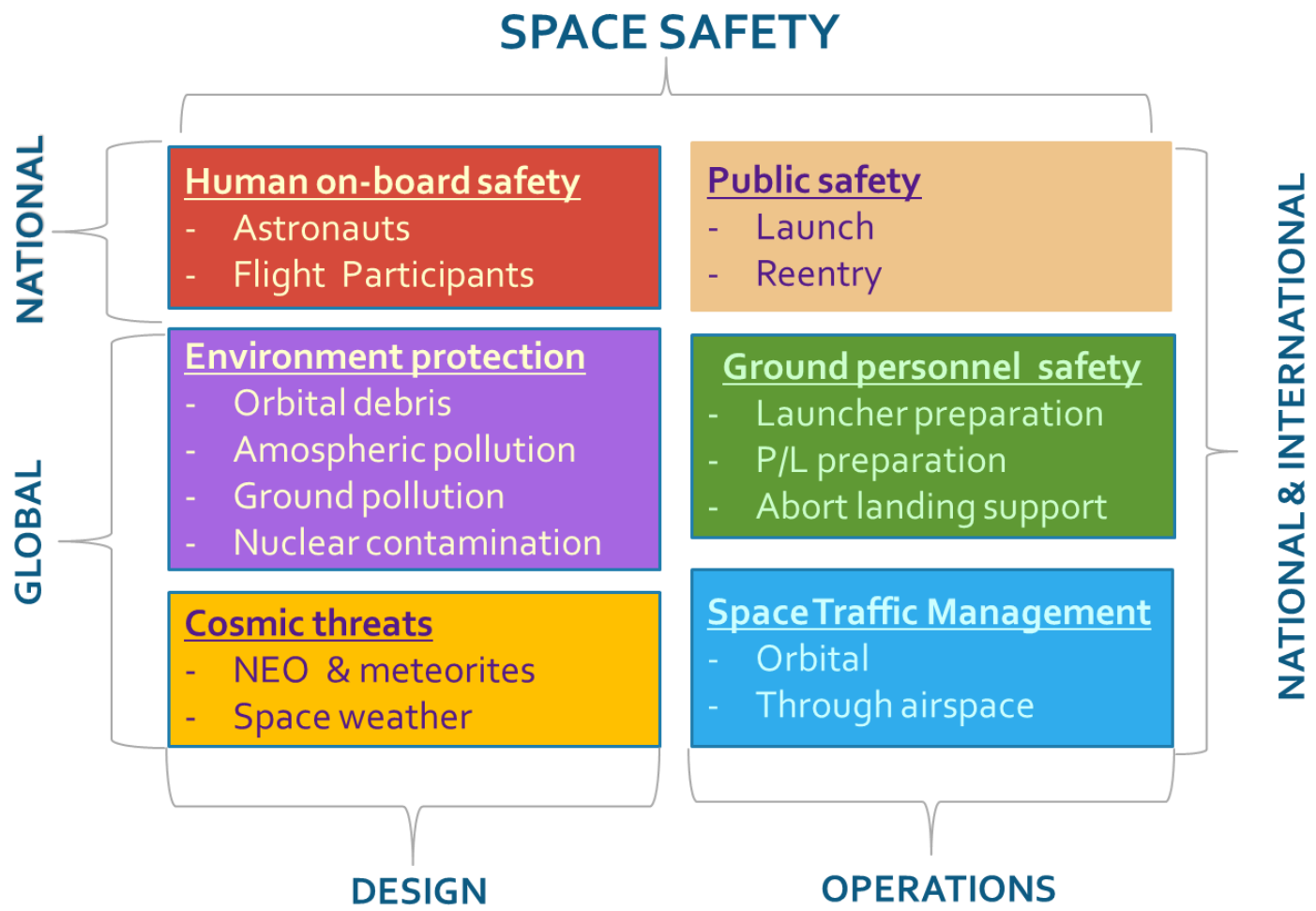
- **Space Traffic Management (STM) consists of:**
  - **safe access into outerspace**
  - **prevention of collisions in outerspace, and**
  - **safe return/reentry from outerspace**

- **Space Traffic Management is an important element of Space Safety because of:**

  - public safety risk (people on ground, at sea or travelling by air) during launch and return/reentry ,

  - risk of loss of important (and sometimes safety-critical) space-based

  - safety risk for human spaceflight

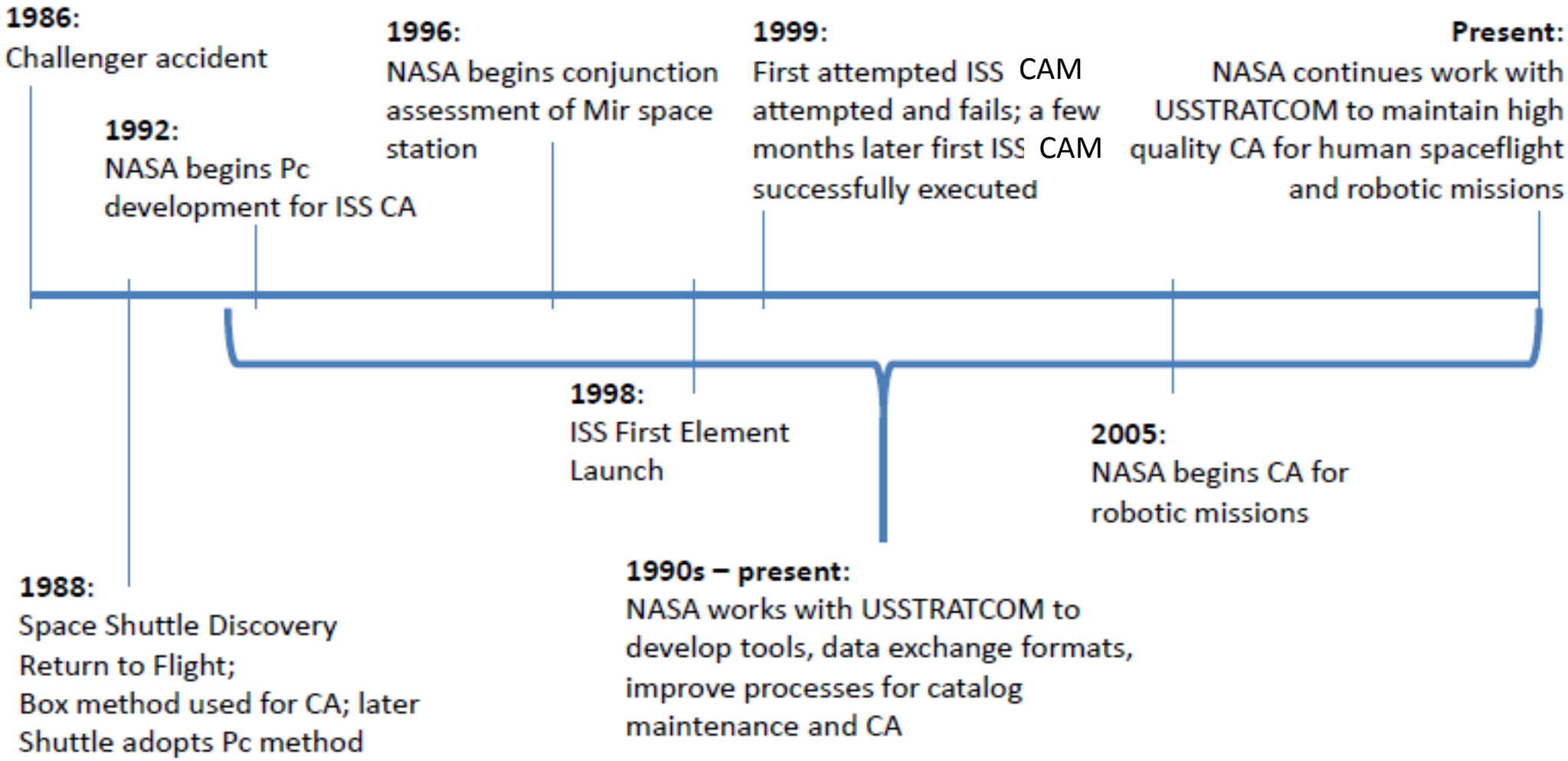

SPACE SAFETY
NATIONAL
GLOBAL
Human on-board safety
- Astronauts
- Flight Participants
Environment protection
- Orbital debris
- Amospheric pollution
- Ground pollution
- Nuclear contamination
Cosmic threats
- NEO & meteorites
- Space weather
Public safety
- Launch
- Reentry
Ground personnel safety
- Launcher preparation
- P/L preparation
- Abort landing support
Space Traffic Management
- Orbital
- Through airspace
NATIONAL & INTERNATIONAL
DESIGN
OPERATIONS

Safety as Driver of STM Techniques Development

Collision avoidance manouvers

- In 1988 NASA started establishing methods for **Shuttle collision avoidance manouvers** based on a fixed box-shape volume around the Shuttle. USSTRATCOM (then called USSPACECOM) would notify NASA when a tracked debris was expected to cross the volume
- The volume was sized based on large worst-case debris uncertainties, independent from the real uncertainty of the specific tracked debris
- The arrival of **ISS**, the largest satellite ever put into orbit (420 tons), and the large amount of propellant required (100kg) to execute a 1 m/s collision avoidance manouver, mandated the development of more precise methods to compute the collision probability
- Such methods require to predict state vector and uncertainties for both debris and satellites at the time of closest approach. The uncertainties (or covariances) are the result of tracking errors and unpredictable changes in the space environmental conditions affecting the orbital trajectory
- Once the method of computing covariances and verifying their accuracy was established in the late 1990's, NASA agreed a **notification format** with USSTRATCOM, the Orbital Conjunction Message (OCM) , that would contain all information required to compute the risk of collision
- NASA defined a ***Red Threshold* at 1x10-4**, and a ***Yellow Threshold* at 1x10-5**, for the performance of collision avoidance manouver, respectively *Shall* and *Should*, depending on operational considerations.

Collision avoidance manouvers (cont'd)



Collision avoidance manouvers (cont'd)

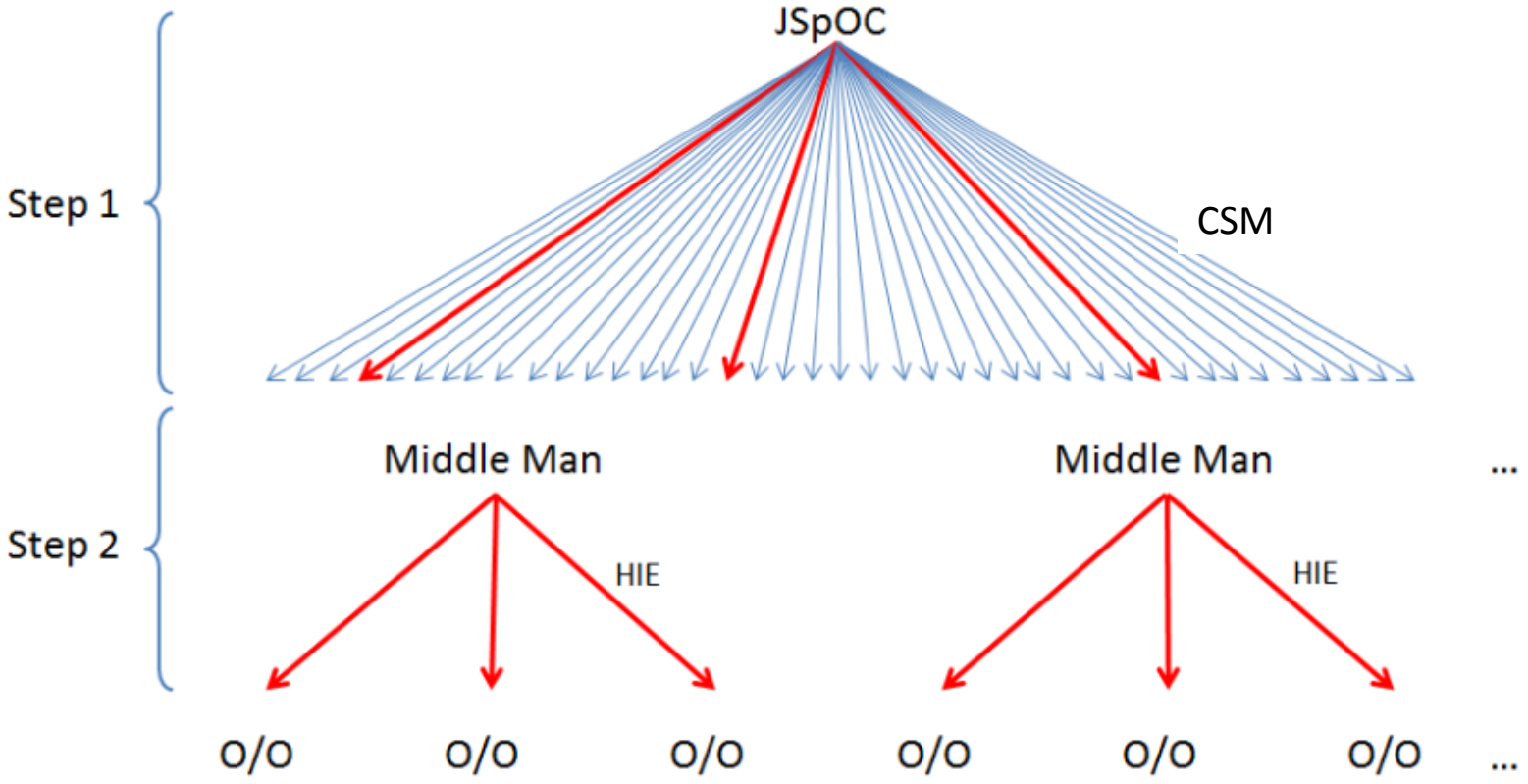
- After the February 2009 collision between U.S. communication satellite Iridium 33 and Russian Kosmos 2251, the **JSpOC** (Joint Space Operations Center) of the USSTRATCOM started sending conjunction information messages called Conjunction Summary Message (CSM), similar to the OCM format of the ISS, to all satellites Owners/Operators (O/O)

- But CSM:
  - are **not direct recommendation** to perform an avoidance maneuver
  - does not take into account the operational constraints of the satellite

- **Satellite Owner/Operator** has to
  - check the CSM for consistency
  - asses the uncertainties for the satellite in the CSM against its own operational data
  - evaluate the risk level and compare with its own threshold criteria
  - decide to perform or not an avoidance action
  - compute the avoidance action

- **Middle-Man** (MM) public services are emerging like:
  - **C**onjunction **A**nalysis and **E**valuation **S**ervice: **A**lerts and **R**ecommendations (CAESAR) by CNES
  - **C**onjunction **A**ssessment **R**isk **A**nalysis (CARA) by NASA –GSFC for unmanned missions
  - Space Data Association (SDA) that brings together satellite operators to share more precise data for collision avoidance and prevention of RF interferences

The raise of STM 'Middle-Man'



- Space objects tracking
- Data communication

- Risk analysis
- Skill & expertise
- Readiness 24/7
- Recommendations

- Decision
- Manouver action

Launch Collision Avoidance (COLA)

Collided objects can be :

- Manned vehicles
- Operational satellites
- Space debris

Risks induced by the collision :

- kill people
- lose the mission and destroy on-orbit assets
- generate new orbital debris

Ariane 5 flight VA217 seen from ISS in February 2014

A launch window is said to have a ***launch collision avoidance (COLA) blackout period*** when the vehicle trajectory is too close to another object already in space. In US, a launch is not allowed if the rocket will pass within 200 km of the ISS

Working on the 'COLA Gap'

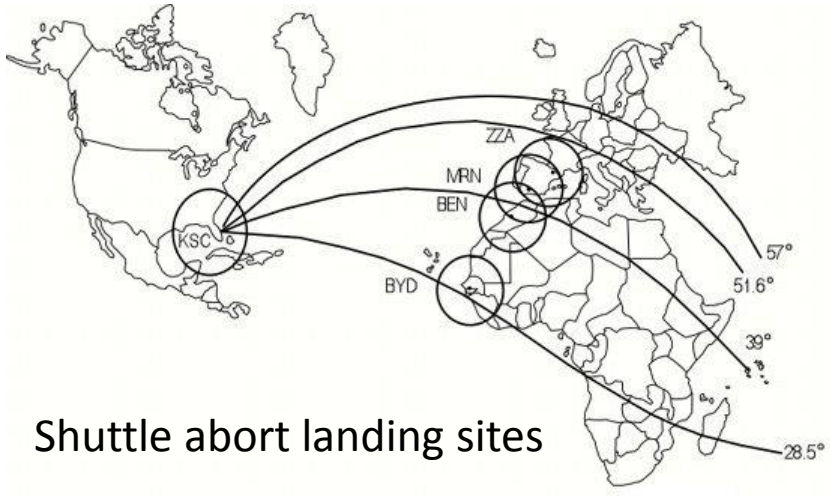
- In 2009 the spent upper stage of the ULA Delta II that had just launched a GPS IIR-20 satellite unexpectedly passed within 20 km of the ISS. This event highlighted a 56-hour period between the end of the launch collision avoidance (COLA) process and the starting of the on-orbit collision avoidance process, because of the time required to initially track a catalog a new objects
- **New probabilistic methods** are currently being implemented to remove such gap. Such methods should be used internationally

> *"Launched objects around the world could impact any other global space assets including existing international Low Earth Orbit (LEO) satellites. It is imperative that launch safety organizations around the world collectively use resources to understand and develop the best method to mitigate the risk of on-orbit collisions because such collisions can dramatically increase the threat from orbital debris impacts on all other on-orbit assets." (*E.Schultz-NASA, P. Wilde-FAA "Mitigation of Collision Hazards for ISS from Globally Launched Objects3, 6th IAASS Conference, Montreal 2013*)*

Launch and re-entry of lifting-body space vehicles

Lifting-body space vehicle (e.g. Dream Chaser) operations raise specific safety issues that cannot be addressed by means of use of 'segregated' airspace as for traditional launch operations:

- **abort mode**, when due to failure or malfunction during the ascent phase the vehicle is not able to achieve orbit and has to use an emergency landing site (i.e. an airport)
- **accident during return**, as happened to the Shuttle Columbia, when the vehicle breaks and fragments while overflying the controlled airspace



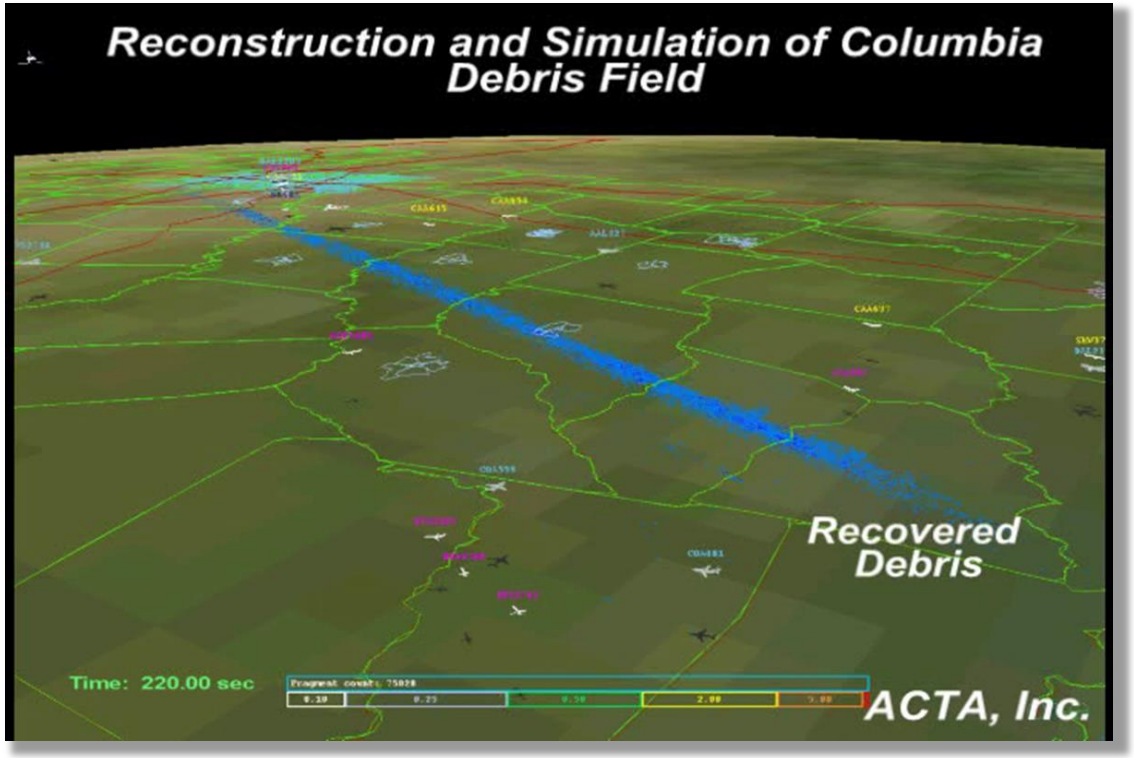
Shuttle abort landing sites

Dream Chaser of Sierra Nevada Corp.*

*SNC is one of five companies bidding for a new round of contracts to transport cargo to and from the ISS

Launch and re-entry of winged space vehicles (cont'd)

Casualty expectations for people in commercial aircraft exposed to the risk of falling fragments from Shuttle Columbia disintegration was **1 in 1000**



STM Requires an Organized International Cooperation

First steps to organize STM internationally

- The responsibility of national space organizations that license launch and re-entry operations (e.g. FAA-AST) should be **extended** to include civil/commercial STM services
- Define **borders and interfaces** between military and civil/commercial STM
- Launch an inter-governmental cooperation between space faring countries for creating **international voluntary STM rules**

ICAO as Model of International Cooperation

- The International Civil Aviation Organization (**ICAO**) was established in 1947 with the mission to serve as the global forum of States for cooperation on safety of air navigation and civil aviation development
- The ICAO convention adopted the use of technical specifications called **Standards And Recommended Practices (SARPs)** in order to achieve "*the highest practicable degree of uniformity in regulations, standards, procedures and organization in relation to aircraft, personnel, airways and auxiliary services in all matters in which such uniformity will facilitate and improve air navigation*"
- The ICAO Convention does not generate any prerogative, right or obligation for individual nationals of the contracting States. Only national laws and regulations apply
- The ICAO Council can make recommendations for changes (to national rules) but "*No contracting State shall be guilty of an infraction of this Convention if it fails to carry out these recommendations.*"
- The ICAO Convention includes does not apply to State aircraft (e.g. military aircraft). State aircraft are, however, required to operate with ***due regard*** for civil and commercial air traffic. [State aircraft are strictly speaking not required to follow air traffic rules. In the vast majority of cases, however, they do because it is in their self interest to do so];

Conclusions

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The **COPUOS Legal Subcommittee** (LSC) may consider establishing a Working Group on Space Traffic Management to develop the following points:

- Space Traffic Management is a safety issue that requires international coordination and uniform rules
- The raise of "Middle Man" (civil space agencies, industrial services providers) could facilitate international cooperation in Space Traffic Management
- As done since long time for Air Traffic Management, safety issues and security issues related to Space Traffic Management should be kept separated to facilitate international data exchange and cooperation in the field of civil/commercial space operations
- Civil space agencies/organizations should lead the establishment of space traffic management rules and data exchange protocols through an international coordination organization similar to ICAO (International Civil Aviation Organization)