

# AREAS OF INTERACTION BETWEEN AIR- AND SPACE-TRAFFIC AND THE ROLE OF SPACE SURVEILLANCE

Holger Krag 29/08/2017

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## Suborbital Flight Routes





- Route layout based on predicted air traffic evolution
- Routes are likely to develop mostly in the nothern hemisphere
- Usage of existing ground infrastructure (cost efficiency, vicinity to major cities) ESA UNCLASSIFIED - For Official Use H. Krag | 29/08/2017 | Slide 2

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# **Space Situational Awareness**

# **Global STM/ATM Integration**

 Identification of key players and stakeholders

[ESA STM Study]

- Contribution of Space Surveillance
  - Space Weather
  - Re-entry Warning
  - Collision Avoidance



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## Space Weather Hazards to Infrastructure





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## Decayed Mass per Year





- Excludes Re-entry Vehicles
- Today 400t per year are launched and about 150t decay
- This corresponds to a total cross-section of about 500m<sup>2</sup> (corresponds to roughly 2 tennis courts)

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## **Atmospheric Break-Up**





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## Special Analysis: ROSAT – Ground Tracks



## https://reentry.esoc.esa.int



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## Ascend and Landing Phases



### FL650 4 ≁ Airspace 4 Vehicle ۰. $\mathbf{H}$ Until Fully Today Gradual reduction in segregation, rigidity too possibly, as technology Integrated allows ELoS to be demonstrated.

## Flight Corridor Handling

**Columbia Accident** 



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1000



500

<u>entry</u>

# **Required NOTAM Areas**



## Russian Federal Space Ag



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## **Fragment Fall Durations**

## Which fragments are relevant?





- FAA-JTCG: > 0.05 g (penetrate of aircraft skin)
- FAA-JTCG: > 300 g (catastrophic event)
- RCC 321: > 1g (windshields and turboshaft piston engines protection)

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## **Spatial Density Computation**





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## Collision Risk in Space – Tracked Objects

• Sample p2p suborbital flight, with a distance of 15,000km and 500km peak height



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A 500km Fearth 200 EARTH

# Control of collision risk by flight delays



• Sample p2p suborbital flight, with a distance of 15,000km and 500km peak height



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# Collision Risk in Space – Small Objects





|  | Particles > 1mm     | Particles > 5mm      | Particles > 1cm      |
|--|---------------------|----------------------|----------------------|
| Impacts/15000km<br>[1/m <sup>2</sup> /15000km] | $1.2 \cdot 10^{-7}$ | 7.2·10 <sup>-9</sup> | 1.5·10 <sup>-9</sup> |

- Assumption: The probability of all catastrophic failure conditions (loss of life &/or vehicle) to SSV and its occupants shall be better than 1x10-4 per flight
- There are a total of 100 potentially catastrophic failure conditions which have an equal share of this budgeted requirement

| SSV shielding capacity (debris size, mm) | Maximum cross-sectional area (m <sup>2</sup> ) |  |  |
|--|--|--|--|
| 1  | 10   |  |  |
| 5  | 100  |  |  |
| 10                                       | 1000   |  |  |

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## ESA SSA Program

FSA



## 100 MEUR 2017-2019

- European Sensor Technology for Space Surveillance
- Space Weather Forecasting
- NEO Detection and Warning

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### Image: Imag Image: Image:

## SSA Networking European SWE Assets





Data archives SSA • SSA SWE Data Centre (Redu) • U

 Federated data repositories

### SSA SWE Coordination Centre

- User Helpdesk
- Space Pole,
  Belgium

### SWE Expert Service Centres (ESCs)





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## **ESA SST Developments**







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ESA SST Data Centre



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## Back-Up

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### Re-entry Break-up Analysis: SCARAB for Cluster-II T = 0.08008 s





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# Annual Mitigation Compliance Review – Clearing Protected Zones

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https://www.sdo.esoc.esa.int/environment\_report/Environment\_Report\_I1R2\_20170427.pdf



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## Flight Information Regions (FIR)





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# Space Weather



Risk register listing the most critical risks and impacts that could occur if space weather conditions are unknown to crew and passengers.

| Cosmic Radiation Forbush Decrease  | Risk                     | Solar Flares   | High Energetic Particles  | Coronal Mass Ejection  |
|--|--------------------------|--|---|--|
| Electromagnetic radiation  | Origin                   | Sun  | Sun / Cosmic Rays   | Sun  |
| Arrival: 8 min<br>Period: 1- 2 hour<br>High-energy particles /                       | Event                    | Electromagnetic<br>radiation X-ray to radio<br>wavelengths   | High-energy particles / proton showers  | Energetic particles in solar wind  |
| Arrival: 15 min up to hour<br>Period: up to several days                             | Duration                 | 1 - 2 hrs  | Solar event: Up to several<br>days<br>Cosmic Rays: Continuous   | Up to several days   |
| Energetic particles in solar wind<br>Arrival: 2- 4 day<br>Period: up to several days | Time<br>until<br>arrival | ca. 8 min  | 15 min up to one hour   | 2 - 4 days (depending on solar wind speed)   |
| Space Weather Overview - Background image courtesy NASA                              | Causes                   | <ul> <li>Enhanced ionization at<br/>the bottom of the<br/>lonosphere (D-Layer)</li> <li>Heating of the<br/>Thermosphere</li> </ul>           | Radiation   | <ul> <li>Solar storm (extreme solar wind)</li> <li>Thermosphere heating</li> <li>Geomagnetic storms,</li> <li>Particle precipitation,</li> <li>Ionospheric disturbances</li> </ul> |
|  | Impact                   | <ul> <li>Navigation (Positioning,<br/>Loss of Lock),</li> <li>Radio Blackouts (Signal<br/>disturbance GNSS)</li> <li>Drag effects</li> </ul> | Radiation damage (Space<br>/Air Crew and Passengers)     SEU, Latchup     Interference     Degradation (Solar cell<br>damage, etc.) | <ul> <li>Internal/External charging</li> <li>Drag effects, Navigation<br/>(Positioning),<br/>Communication (HF),<br/>Geomagnetic induced<br/>currents</li> </ul>                   |
|  | Forecast                 | No   | Yes   | Yes  |

Yes

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Table 3: Risk register associated with unawareness of space weather events

Yes

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Yes

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Nowcast

## Integrating STM and the ATM system



STM & ATM Handover/ Handback. Space Weather Advanced RNP operations Report updates Collision risk assessment & CTA Enhanced safety nets trajectory cross-checks Automated support for traffic complexity assessment En-route TMA ASAS s pacing Trajectory-based tools Mission trajectory Network Enhanced TMA Time based CIUT to TTA Information sharing and using RNP based operations Sector tearn operations business trajectory Airport/ Spaceport Remote tower CNS rationalisation AMAN/DMAN integration Collision avoidance including multiple airports Ground situational Collaborative NOP awareness Digital Approach and departure in tegra ted separations briefing Airport/spaceport safety nets vehicles Space Weather AMAN extended Report updates depature sequencing information sharing to en-route airs pace Enhanced airport/ spaceport safety nets Integrated flight planning & LVPs using GBAS Integrated surface management DL scheduling Space DMAN integrated with Weather surface management surface movement planning and routing Reports Collaborative a irport Integrated surface management InitialSWIM\* includes the following PCP Essential Operational Changes: Add-on Operational Changes for STM common infrastructure components;

- SWIM infrastructure and profiles
- · aeronautical information exchange;
- meteorological information exchange;
- · cooperative network information exchange;
- flight information exchange.

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Operational Changes

PCP Essential Operational Changes

New Essential Operational Changes

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## Weltraumüberwachung





## Radar-Prototyp





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# Space Debris and Space Surveillance and Tracking

## Spatial densities of non-traceable objects as a function of altitude and declination



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## Campaign Setup





NASA DC-8 Research Aircraft



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## What is "Space Weather"?





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## Space Weather Hazards to Aviation

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Significance increasing rapidly

Satellite navigation errors

Telecommunicationdisturbances:HF radioSatellite links

Increased radiation doses

- Cosmic background radiation
- Solar energetic particle events

Ground surveillance system disturbances

- Radars
- Transponders

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## **Cross-Track Dispersion of Fragments**



- Assumption of Gaussian distribution is limited
- Sometime objects beyond 100km



The set of th

### $N\Delta V \Delta RF\Delta c$



WORLD-WIDE NAVIGATIONAL WARNING SERVICE - NAVAREAS\*



# Safety & Reliability



## **Columbia Accident**



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## Results

• Maximum allowed density for expected number of impacte  $E_N < 10^{-8}$   $E_N$ 

$$\rho < \frac{E_N}{v \cdot A \cdot t}$$

- Result: 3.64\*10<sup>-14</sup>/m<sup>3</sup>
- Corresponds to 7σ
- And this corresponds to 82.6km

| • 5 | Synthesis: | sis:              |                       |                     |     |    |         |
|-----|------------|-------------------|-----------------------|---------------------|-----|----|---------|
|     |            | ,                 | Distance<br>explosion | required<br>delta-v | due | to | 82.6km  |
|     |            |                   | Mean valu             | le offset           |     |    | 2.9km   |
|     |            |                   | Wind/lift             |                     |     |    | 15km    |
|     |            |                   | Sum                   |                     |     |    | 100.5km |
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