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SWIM IN SPACE WITH COMRADES IN THE AIR

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All the future air traffic participants are requested to act as system wide information management (SWIM) communicating sub-systems by the future Single European Sky Air Traffic Management Research (SESAR) SWIM "Intranet for ATM" concept. Against the background of the global character of future commercial space transportation (CST) operations and the associated SWIM harmonization need referring the U.S. Next Generation Air Transportation System (NextGen) and SESAR, a solution based on the already harmonized data format standards Aeronautical Information Exchange Model (AIXM) and Flight Information Exchange Model (FIXM) had been realised. The new version's ability to deliver air traffic information about flights that will interfere with the hazard area and might need special attention by benefiting from Automatic Dependent Surveillance - Broadcast (ADS-B) information fetching is presented.

I. INTRODUCTION

SWIM represents the infrastructure that enables all future air traffic management (ATM) participants to share relevant real-time, aeronautical, weather and flight information based on a common understanding and situational awareness, thus freeing new collaboration benefit potentials. Facing the challenge to build a fundament for seamless space / air traffic integration of future "landing like an aircraft at an airport" spacecraft, SWIM compliant generation and fast distribution of accurate emergency information will be needed.

II. THE VALUE PROPOSITION

Looking at the advent of commercial space and the associated impact on standard air traffic requires reaction potential to space / air traffic interchange influences, especially in the case of emergency situations, where having a shared, unambiguous situational awareness of all airspace stakeholders is of utmost importance. The presented use case addresses the threat of falling down space debris, caused by a fatal breakup event of a spacecraft, on normal air traffic. Aircraft within the debris footprint have to leave this area as soon as possible in order to avoid being hit by this fatal "rain". Knowing the debris hazard zone, characterized by its evolvement over time and altitude, as well as having an air traffic situation picture are essential for the identification of affected aircraft. For this purpose, a near real-time information sharing solution called "SpacecraftReentryHazardAreaServer" for normal air traffic protection purposes in the event of a future space vehicle breakup had been developed. In addition to its service functionality of calculating and providing the debris hazard zone based on the associated spacecraft position[1,2], the new version identifies aircraft that might be affected (Fig. I) and generates dedicated traffic information that can be consumed as a SWIM compliant web service. The general data flow is shown in Fig. II.

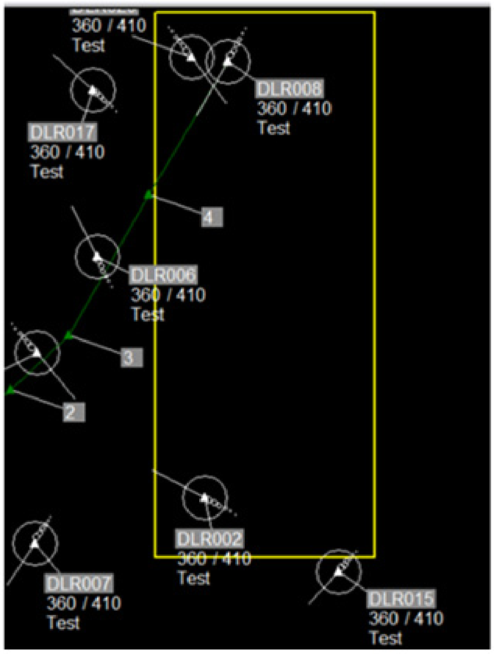

Fig. I: Aircraft in hazard area

Position information of a spacecraft is sent continuously from the spacecraft operations centre to the SpacecraftReentryHazardAreaServer application (1. in Fig. II). Air traffic position information (2. in Fig. II) is retrieved by sending GET requests to an ADS-B data provider. Informing the server application of a concrete breakup event (3. in Fig. II), triggers the identification of affected aircraft referring to the last calculated hazard zone altitude distribution. These identified aircraft are sent back as the event reply (4. in Fig. II).

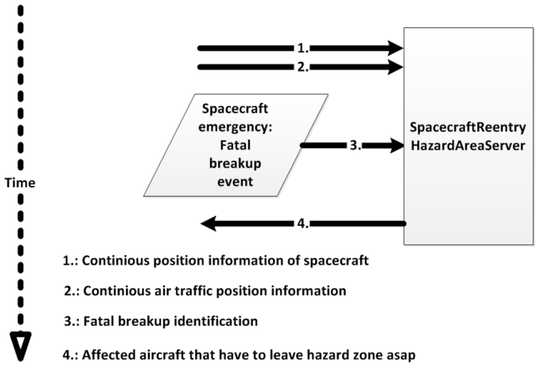

Fig. II: General data flow

III. THE CHALLENGE

The challenge of protecting normal air traffic against potential spacecraft debris can be condensed to the following actions:

- Precise and quick assessment of the impact area on air traffic,
- Quick identification of the affected participants.

Although standard voice / phone call communication and coordination could face this challenge for low traffic amount sectors, taken into account that on average, first fragments reach the upper airspace (i.e. 60000 ftmsl) 10 minutes after break up[3], automated information distribution should be envisaged, accompanied by the following advantages:

- Faster distribution without mistakes, misunderstandings or ambiguities,
- Information distribution jobs are not forgotten,
- Higher precision of determination (the right quality data, at the right time, to the right target).

IV. THE SOLUTION

Precise and quick assessment of the impact area is realised by the SpacecraftReentryHazardAreaServer's ability to use Extensible Markup Language (XML) documents as the fundamental unit of storage for vehicle specific hazard area representations, in line with the XML data management of SWIM[2]. For the identification of the endangered air traffic, the edge coordinates of the spacecraft hazard zone are used in terms of refining their biggest latitude / smallest longitude and smallest latitude / biggest longitude pairs' data as zone parameters for the ADS-B traffic info fetching GET requests (Fig. III).

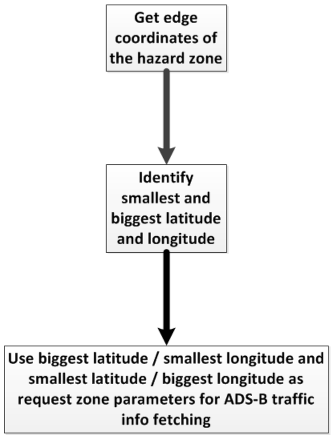

Fig. III: Derivation of zone request parameters

These zone parameters are part of the TargetUrl input for the http::geturl command, which returns a token value for further Hypertext Transfer Protocol (HTTP) transactions. If this return is successful, the Uniform Resource Locator (URL) data is consumed by using the token as the transaction parameter for the http::data command (Fig. IV).

```
if {[catch {set TargetToken [http::geturl $TargetUrl -strict 0]} ErrMsg]} {
   puts "Fetching FAILED: $ErrMsg"
} else {
   set FetchData [http::data $TargetToken]
}
```

Fig. IV: Traffic data fetching

For further processing, the fetched air traffic data is converted to dictionaries with order-preserving mapping from arbitrary keys to arbitrary values (Fig. V).

```
set tobeProcessed [json::json2dict $FetchData]
```

Fig. V: Dictionary conversion

This conversion shows a nearly traffic amount independent per aircraft performance (Fig. VI), thus being the right choice to base further processing on.

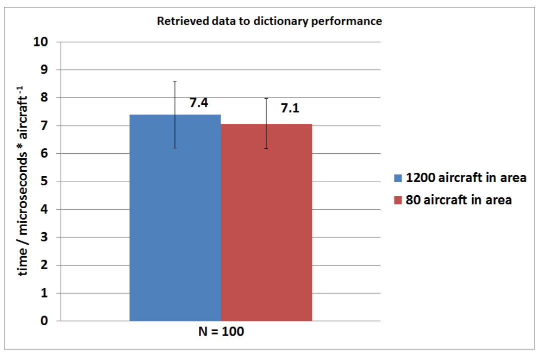

Fig. VI: Data conversion performance

For each aircraft, a SWIM compliant hazard warning message (Fig. VII) is sent out to the service client (e.g. spacecraft operation centre) using the notification message pattern (Fig. VIII). Experiments on a local test client for the time until all notifications are received were performed for two use cases, 1200 and 80 affected aircraft in a hazard area (Fig. IX).


```xml
<?xml version="1.0" encoding="UTF-8"?>
<aixm:InformationService gml:id="URGENTINFO_1" xmlns:aixm="http://www.aixm.aero/schema/5.1.1"
    xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.aixm.aero/schema/5.1.1/message AIXM_BasicMessage.xsd">
    <aixm:timeSlice>
        <aixm:InformationServiceTimeSlice gml:id="XXX123">
            <gml:validTime>
                <gml:TimeInstant>
                    <gml:description>HAZARD DEBRIS RAIN COMING DOWN AT NOW +10 MIN</gml:description>
                    <gml:timePosition>2018-12-06T17:00:00.000Z</gml:timePosition>
                </gml:TimeInstant>
            </gml:validTime>
            <aixm:interpretation>SNAPSHOT</aixm:interpretation>
        </aixm:InformationServiceTimeSlice>
    </aixm:timeSlice>
</aixm:InformationService>
```


Fig. VII: SWIM compliant hazard warning message

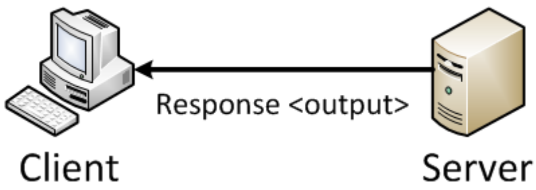

Fig. VIII: Notification message pattern

Although the extreme use case of 1200 aircraft and the related notifications' reception time of nearly two minutes (blue bar in Fig. IX) still give each aircraft nearly 8 minutes (10 minutes[3] – 2 minutes) for danger zone evacuation, actual developments focus on the realisation of a sub zoning proxy solution (Fig. X) which automatically scales traffic amount dependent sub zones per server instance in a way, keeping the notifications' reception time always below 10 seconds.

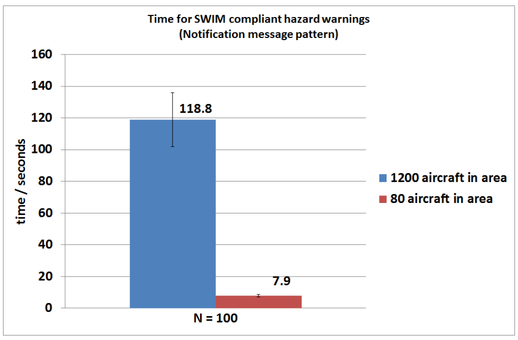

Fig. IX: Notifications' reception times

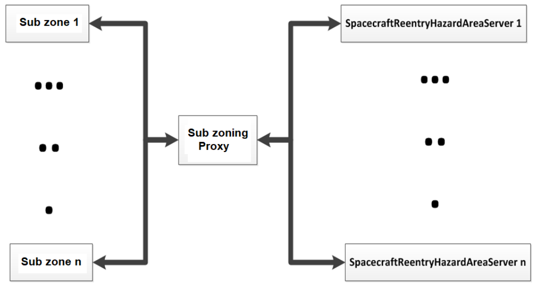

Fig. X: Sub zone scalability

V. OUTLOOK

Faster information distribution and higher precision of determination will evolve their whole potential by being integrated in a fully enabled Aircraft Access to SWIM (AAtS) (NextGen) / SESAR SWIM Air-Ground (the European version of AAtS) solution. AAtS / SWIM Air-Ground represent the airborne component of the ground based SWIM Service Oriented Architecture (SOA). It will enable aircraft to participate in SWIM based collaborative decision making, thus giving the possibility to integrate direct hazard zone information flow to the pilots of endangered aircraft. Current concept validation environment preparations for an evaluation by a complex ATM integration human-in-the-loop simulation under full traffic conditions extend to:

- Represent SWIM AIR (Fig. XI) entities by simulated aircraft in X-Plane[*] with interfacing electronic flight bag (EFB) software prototypes,
- Integrate the SWIM Ground (Fig. XI) spacecraft operation centre representation (SpacecraftReentryHazardAreaServer),
- Provide the approaching spacecraft by the SpaceLiner simulation model[4],
- Integrate Scilab / Xcos[†] modules for satcom simulation purposes.

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[*] X-Plane 11 flight simulator (https://www.x-plane.com)

[†] Scilab numerical computation software (https://www.scilab.org)

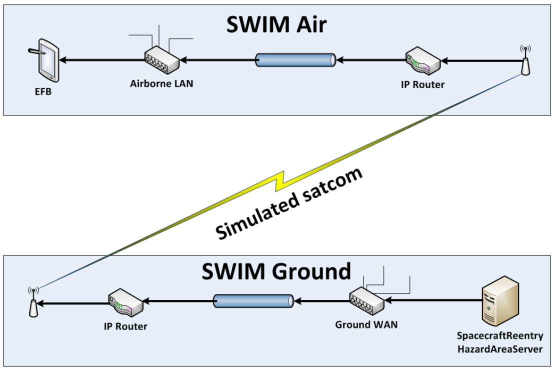

Fig. XI: SWIM Air-Ground simulation

VI. SUMMARY

The paper presents the need of SWIM compliant generation and fast distribution of accurate emergency information to face the air traffic integration challenge of future space traffic. A notification solution with first test data results against two different affected air traffic amounts is introduced with an outlook to future developments, covering air-ground human-in-the-loop validation simulation aspects.

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[1] F. Morlang, J. Ferrand, R. Seker, 2017, Why a future commercial spacecraft must be able to SWIM, Journal of Space Safety Engineering, Volume 4, Issue 1, pages 5-8

[2] F. Morlang, 2017, News from SWIM in space, 9th International Association for the Advancement of Space Safety Conference – Toulouse

[3] W. Ailor, P. Wilde, 2008, Requirements for warning aircraft of reentering debris, 3rd International Association for the Advancement of Space Safety Conference – Rome

[4] F. Morlang, S. Kaltenhaeuser, 2016, VS controller design for simulation of the SpaceLiner suborbital two-staged reusable launch vehicle using SIFCDL (Simulation Integrated Flight Controller Development Lab), 3rd Annual Space Traffic Management Conference "Emerging Dynamics" – Daytona Beach