Test on the New SSA System of JASDF

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Abstract

The new SSA system of Japan Air Self Defense Force (JASDF) is currently under construction toward the operation from JFY2023. JASDF plans to test the major functions of the system before the operation collaboratively with Japan Aerospace Exploration Agency (JAXA), related manufacturing companies and U.S. partners. These efforts would contribute to strengthen the international cooperation on SSA with U.S. and other friendly nations, and to ensure the stable use of outer space in the future.

1. INTRODUCTION

A. Background

Outer space is an essential region nowadays which supports any activities on the globe including security, economic and scientific issues. Various kinds of satellites have been launched for observation, communication, broadcasting and positioning, making outer space key infrastructure for both the public and private sectors.
On the other hand, the increasing population of space objects, either active or defunct satellites, or more generally, space debris, requires us to consider emerging risks toward the conventional activities in outer space. For the stable use of outer space in the future, many countries have been making proactive efforts for maintaining the peace, and the collaborative Space Situational Awareness (SSA) becomes more and more important for all over the world.

B. Governmental Strategic Documents

To cope with the emerging risks, the Government of Japan plans to construct the new SSA system in Japan based on the National Space Policy. Along with the National Security Strategy on Dec. 2013 and other governmental strategic documents, Japan starts to enhance its SSA capability. Especially, the 3rd Basic Plan on Space Policy on Jan. 2015, and the National Defense Program Guideline and Mid-Term Defense Program on Dec. 2018 accelerate the initiatives. The 3rd Basic Plan on Space Policy stipulates Japan will construct the operational SSA framework integrated with Japan Ministry of Defense (JMOD) and Japan Aerospace Exploration Agency (JAXA), collaboratively with the U.S. Forces, as shown in Fig.1.

Fig. 1. Grand Design of SSA Structure in Japan [1]

C. SSA in JMOD / SDF

The latest National Defense Program Guideline and Mid-Term Defense Program on Dec. 2018 describe that the Self Defense Force (SDF) will build a structure to conduct persistent ground- and space-based SSA as shown in Fig.2. Along with the initiatives, Japan Air Self Defense Force (JASDF) has been constructing the ground-based new SSA system which consists of an operation system and a radar, toward the operation from JFY2023. To start the operational phase smoothly, JASDF is working with JAXA from the construction phase, because JAXA has led a lot of space projects in Japan for a long time, and has hands-on expertise in the space field including SSA [2]. Currently, JASDF is developing the operation system, and the radar for GEO observation, while JAXA is developing a radar for LEO observation and an optical telescope for GEO observation. Combined with JASDF's and JAXA's facilities, we aim to conduct SSA operations effectively.

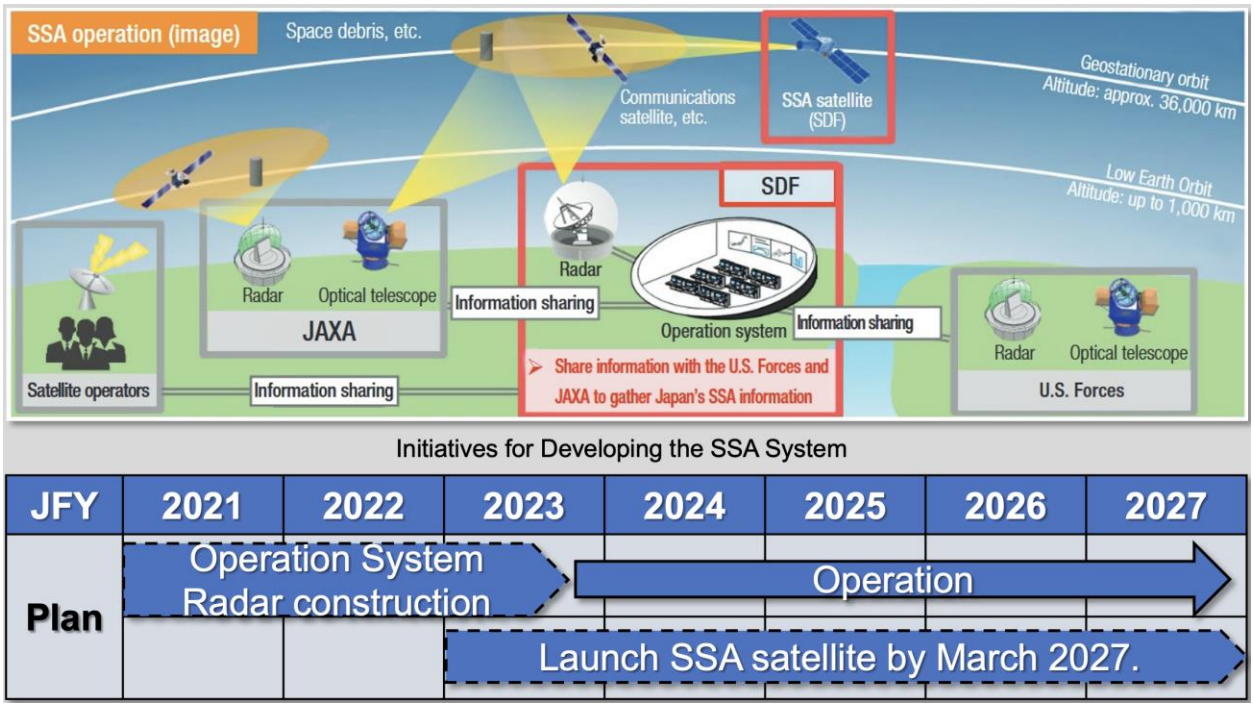

Fig. 2. Initiatives for Developing the SSA System in Japan

2. MISSIONS

A. SSA Capabilities

U.S. Air Force doctrine defines SSA as "the requisite foundational, current, and predictive knowledge and characterization of space objects and the operational environment upon which space operations depend – including physical, virtual, information, and human dimensions – as well as all factors, activities, and events of all entities conducting, or preparing to conduct, space operations." [3]. Fig.3 shows the overview of SSA functional capabilities in the USAF doctrine. The capabilities of SSA system, such as characterization, detect / track / identify, threat warning / assessment, data integration & exploitation, support planners', operators' and decision makers' performances on strategic, operational and tactical acts. This view is helpful to understand the requisite capabilities of our new SSA system.

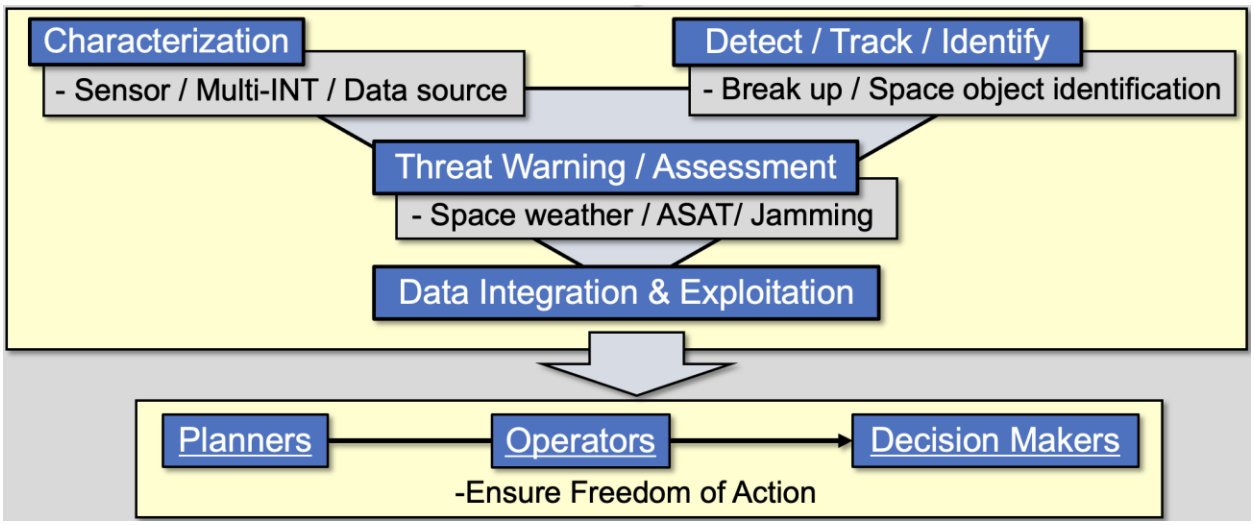

Fig. 3. SSA Functional Capabilities

B. Purposes and Means of the Test on the new SSA system of JASDF

As mentioned above, the new SSA system of JASDF is composed of an operation system and a radar. Among them, the operation system will be installed in JFY2021. Generally, when new equipment is introduced to a current system, test and evaluation of the equipment are needed to ensure the adequate operation. Electronic Development and Test Group (EDTG) is the group of JASDF for the test and evaluation of ground-based electronic equipment. EDTG is going to test the operation system in JFY2022, and subsequently, will test the radar by JFY2023.
Commonly, a SSA system has the capability of space objects' orbital analysis as a core function, utilizing the public database of U.S. Strategic Command's two-line element (TLE) data. On the other hand, there are statistical studies to improve the accuracy of the orbital analysis using the TLE data [4, 5, 6] for maneuver detections, conjunction assessment and re-entry missions because the TLE data isn't updated in real-time and so on.
The new SSA system of JASDF will have similar capability of the orbital analysis, which should be tested appropriately. Although the accuracy of the orbital analysis depends on the number of sensors, the accumulation of the sensors' data and the statistical analysis, we will use reference trajectory (on-board positioning data) for the test as the first step to move forward the system to operational phase from JFY2023.
Considering the SSA capabilities and the immediate supports for the operations, we plan to put the purposes and the means for the test dividing into two terms. For short term, the purpose and the mean are to obtain the criteria to help decision making under uncertain orbital information, and to confirm the accuracy and the reliability of output data from the SSA system, respectively. For long term, those are to estimate orbital trajectories as precisely as possible, and to confirm the algorithm and/or the method of the SSA system, respectively.

3. TEST PLANS

A. Overview

The basic functions of a SSA system are considered to be "Observation Planning" and "Orbital Estimation / Determination", and "Orbital Estimation / Determination" is divided into "Conjunction Analysis", "Re-entry Prediction", "Catalogue Updating" and "Risk Analysis and Report" [7]. EDTG will test the operation system and the radar of the new SSA system of JASDF from JFY2022 to JFY2023, especially the functions of "Observation Planning", "Conjunction Analysis" and "Re-entry Prediction" as the first step.

B. Observation Planning

The observation planning is one of the basic functions of a SSA system. It plans which space objects will be tracked, and determines the timing of the observation. For example, the direction and the timing of the radar beam will be commanded based on the planning. The new SSA system of JASDF is going to be connected with the SSA system of JAXA [8] as shown in Fig.4, but the applications for the observation planning are different with each other. Thus, the function of observation planning should be coordinated for effective observation planning as a whole through comparisons between the two systems.

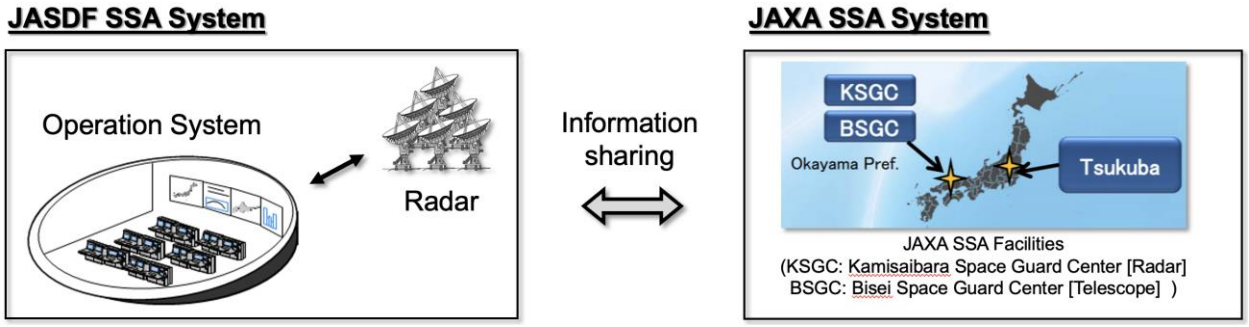

Fig. 4. SSA systems of JASDF and JAXA

C. Orbital Estimation / Determination

Orbital estimation / determination is the basic function of a SSA system as well. The accuracy of the estimation / determination of the orbit of space objects will strongly affect the relevant functions, such as conjunction analysis, re-entry prediction and so on.

a. Conjunction Analysis

The basic sequence of the conjunction analysis is as follows, tracking debris, estimating orbits, analyzing the collision risks, and planning debris avoidance maneuver. As mentioned above, the orbital estimation is significant for the conjunction analysis. Fig.5 shows the images of position error calculations for space objects in the orbital estimation. The left picture of Fig.5 shows the idea of orbital estimation from the input data [9]. The right picture of Fig.5 shows error ellipsoids of two space objects, which mean large error in red and small error in yellow. Naturally, when the accuracy of orbital estimation is low, the error ellipsoid becomes larger, which means the collision risk would be high, but the fact is uncertain. To confirm the accuracy of our new SSA system of JASDF during the test as much as possible, we will use the tool "STK" of AGI to simulate the collision probability of the actual objects in outer space such as satellites and so on. To improve the accuracy of the conjunction analysis, we will accumulate operational data in JASDF and collaborate with JAXA, related manufacturing companies and U.S. partners.

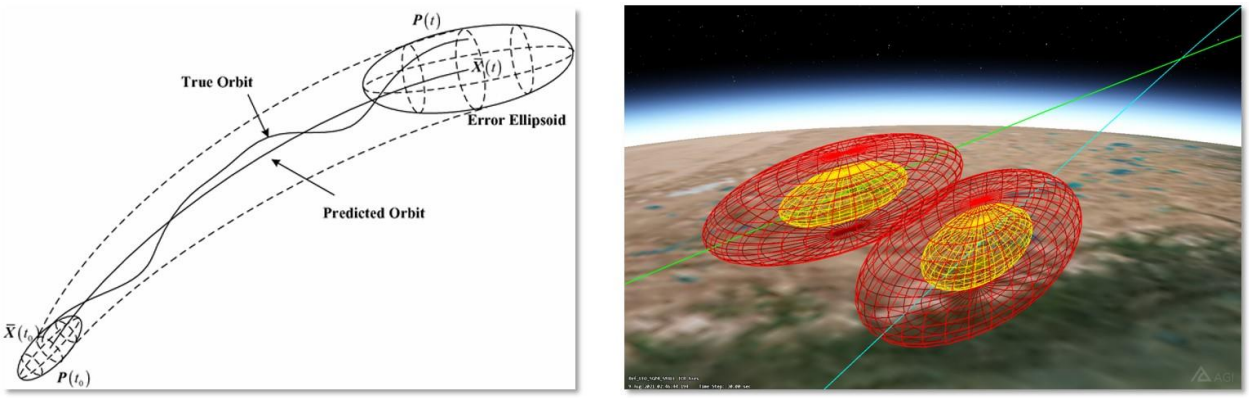

Fig. 5. Images of position error calculations for space objects

b. Re-entry Prediction

The basic sequence of the re-entry prediction is as follows, estimating trajectory, break-ups, and ground impact position / time. In terms of the re-entry prediction, estimating those values is not easy because of many factors such as atmospheric drag, attitude of the object's body, and so on. To confirm the accuracy of the new system as much as possible, we plan to compare the output with the data of actual re-entry missions collaboratively with the IADC (Inter-Agency Space Debris Coordination) campaigns. Again, to improve the accuracy of the re-entry prediction, we will accumulate operational data in JASDF and collaborate with JAXA, related manufacturing companies, U.S. and friendly nations.

4. SUMMARY

Government of Japan plans to construct the new SSA system based on the National Space policy. EDTG is going to test the operation system of the new SSA system of JASDF in JFY2022, and subsequently, will test the radar by JFY2023. To confirm the accuracy of the system as much as possible, we will use the tool "STK" of AGI to simulate the collision probability of the actual objects in outer space such as satellites and so on. Besides, we will compare the output with the data of actual re-entry missions collaboratively with IADC campaigns. To improve the accuracy of the estimation, we will accumulate operational data in JASDF, and collaborate with JAXA, related manufacturing companies, U.S. and friendly nations. These efforts would contribute to strengthen the international cooperation on SSA with U.S. and friendly nations, and to ensure the stable use of outer space in the future.

5. REFERENCES

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