# Current Status of Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

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## Introduction

The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) was designed to be aboard the Japanese Experiment Module (JEM) on the International Space Station (ISS) as a collaboration project of Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). Mission Objectives are: i) Space demonstration of super-conductive mixer and 4-K mechanical cooler for the submillimeter limb-emission sounding in the frequency bands of 624.32-627.32 GHz and 649.12- 650.32, and ii) global observations of atmospheric minor constituents in the stratosphere ($O_3$, HCl, ClO, $HO_2$, HOCl, BrO, $O_3$ isotopes, $HNO_3$, $CH_3CN$, etc), contributing to the atmospheric sciences.

## 1 SMILES Payload

Figure 1 shows a block-diagram of SMILES payload instrument and some pictures for the components. The Submillimeter Antenna (ANT), Submillimeter Receiver (SRX), Intermediate Frequency Amplification Section (IFA), and Radio Spectrometer (AOS) comprises the main part of the payload. The SMILES is equipped with a heterodyne superconductor-insulator-superconductor (SIS) receiver to be operated in the 625/650 GHz band as a limb-emission sounding radiometer. The SMILES has a mechanically scanning elliptical offset-Cassegrain antenna with diameters of 40 cm x 20 cm to achieve an altitude resolution of about 3 km at the tangential altitude ranging from upper troposphere (10 km) to lower mesosphere (60 km) from the orbit of the ISS.

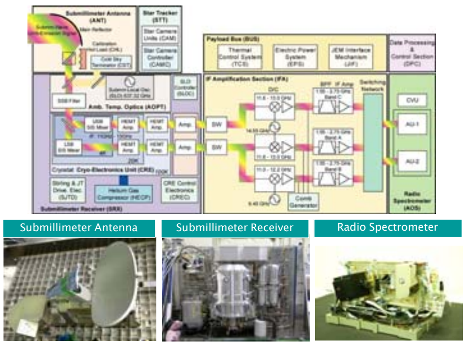


**Figure 1 Block diagram of JEM/SMILES payload**

**Figure 2 SMILES from the backside**

Figure 2 shows a view of the SMILES payload from the backside. The envelope of the SMILES payload mainframe structure has a dimension of 1.85 m x 1 m x 0.8 m. The total mass of the payload is less than 500 kg. The electrical power consumption of the payload is less than 900 W for normal operation.

## 2 SMILES Observation

One of the most unique characteristics of the SMILES observation is its high sensitivity in detecting atmospheric limb emission of the submillimeter wave range (640GHz). The ISS has a circular orbit with an inclination angle of 51.6° and with an orbital period of 93 minutes. In order to measure high-latitude regions, the antenna beam is tilted 45° degrees left from the direction of orbital motion, enabling SMILES to observe latitudes from 38°S to 65°N (Figure 3).

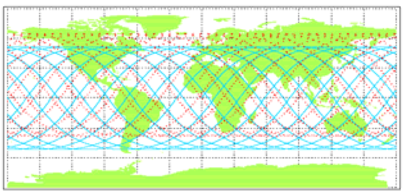

**Figure 3 Measurement positions (red) along the ISS orbit (blue)**

With its high sensitivity the SMILES observation will provide superior global data on several radical species crucial to the ozone chemistry ($O_3$, HCl, ClO, HOCl, BrO, $HO_2$ etc.) Figure 4 summarizes the result of simulation studies estimating errors on the basis of the single scan for the mid-latitude case. About species with larger errors such as BrO, some averaging in space and/or time will reduce the error levels.

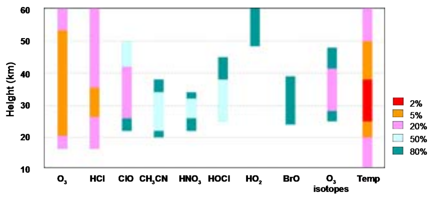


**Figure 4 Error estimation for the mid-latitude case based on the single scan**

## 3 Scientific targets of SMILES

Not only in the polar latitudes, but also in the mid- and lower latitudes, ozone depletion is critical whole the globe. Recovery of the ozone hole over the Antarctica is estimated around 2060- 2070, but there is very big uncertainty in association with the Cl and Br chemistries (WMO, 2006). Since the SMILES mission is distinguished as that focusing on the detailed halogen chemistry related to ozone destruction, we will aim at the following scientific targets.

### 3.1 Bromine budget

Limited BrO measurements so far suggest that in addition to long-lived source gases (halons and methyl bromide), very short-lived (< 6 months) source gases likely contribute to $Br_y$ by about 5 pptv. This difference can be important for $O_3$ concentrations in the lower stratosphere (Salawitch et al., 2005). BrO measurements by SMILES will provide further constraints to $Br_y$ level, which affects $O_3$ chemistry in the lower stratosphere.

### 3.2 Inorganic chlorine chemistry

*Partitioning within $Cl_y$ in the upper stratosphere*: Inclusion of the reaction ($ClO+OH \rightarrow HCl+O_2$) results in a better agreement with observed [ClO]/[HCl] ratio and $O_3$ trend in the upper stratosphere. SMILES [ClO]/[HCl] measurements can be utilized further systematic test on $Cl_y$ partitioning.

*HOCl Production*: There is a factor of 2 uncertainty in the rate constant for the reaction ($ClO+HO_2 \rightarrow HOCl+O_2$). It directly affects HOCl levels, while it does not affect ClO and $HO_2$ levels. $ClO+HO_2$ cycle can be the most efficient $O_3$ loss process within the cycles involving ClO in the lower stratosphere, and then important for $O_3$ trend. SMILES HOCl measurements with ClO and $HO_2$ can be used to assess importance of the $ClO+HO_2$ cycle.

*Global ClO distribution*: The background $ClO_x$ level is important to quantify the in-situ $O_3$ loss at mid-latitudes, though its global distribution with high precision has not been known yet. SMILES will make much more accurate measurements on the global ClO distribution. Also measurements of ClO, HCl, HOCl, and $HO_2$ can provide important insights into the $Cl_y$ chemistry.

## 4 Results from the functional test

Here are some results from the functional test. Noise and gain performances of SRX are found good within the specification (Figure 5). Figure 6 shows an example of calculated and phase-retrieved far-field beam pattern at 637.32 GHz, indicating close match with each other. Gas cell measurements for several species at several conditions are shown in Figures 7 and 8. All these results confirm expected performance for each of the elements.

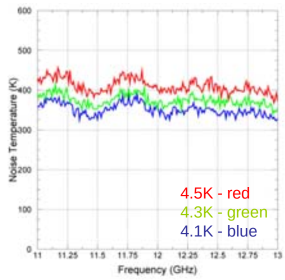


**Figure 5 SSB noise temperature of the submillimeter receiver**

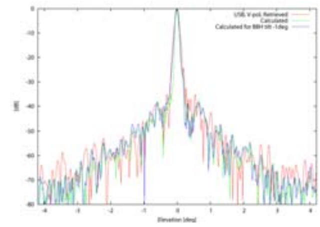

**Figure 6 Example of measured far-field antenna beam pattern using phase retrieval method**

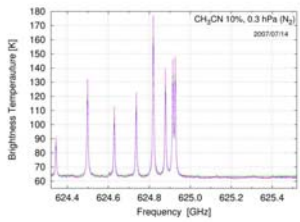


**Figure 7 Gas cell measurement for 10% $CH_3CN$**

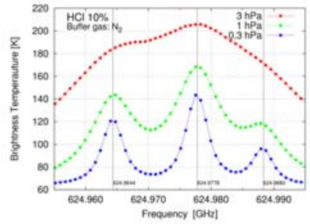


**Figure 8 Gas cell measurement for 10% HCl**

## Summary

- SMILES will make measurements on several radical species crucial to the ozone chemistry with high-sensitivity observations.
- The system integration of SMILES has been done, and now it is in the final phase of the function test.
- SMILES will be scheduled for the launch using H-II Transfer Vehicle (HTV) in 2009 summer.

For the detailed description you will find the mission plan in the following.

http://smiles.tksc.jaxa.jp/document/indexe.html

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