ISS材料劣化実験における
原子状酸素フルーエンス計測法に関する一考察

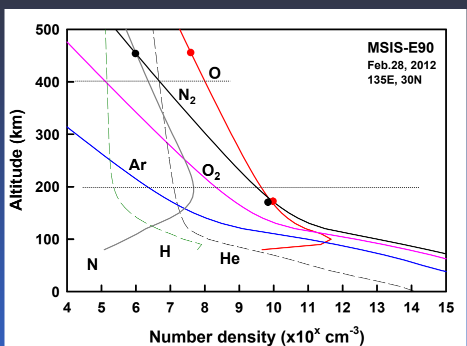
第15回宇宙環境シンポジウム
2018年10月30日, 仙台

[1]神戸大学, [2]NASA-GRC

田川雅人[1], 藤本友介[1], 大倉僚太[1], 白川遼[1], 井出航[1], 横田久美子[1],
Kim K. de Groh[2], Bruce A. Banks[2]

A part of this study was supported by the Grant-in-Aids for Scientific Research contract #26289322, 18H101624 and 18K18912; and also by the Coordination Funds for Promoting Aerospace Utilization from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

Natural gas densities in sub-LEO region



AO density increases more than 2 orders compared with a conventional LEO conditions.

1 year AO fluence @450km is reached within 1 day @180km.

Altitude profile of densities of atmospheric components calculated by MSIS-E90 atmospheric model. Parameters for this calculation are: Date: 2012 Feb. 28 (relatively low solar activity period), Latitude: 30°, Longitude: 135°, Local time: 12H.

-Density of AO increased more than 2 orders higher than that in 450 km
-Density of N_2 increased more than 3 orders higher (Composition: 1% → 50%)

-Effect of N_2 collision on AO-induced erosion has not been become clear.

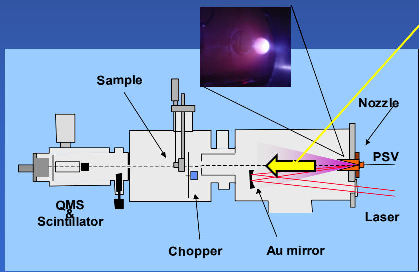
New system

In order to study undecomposed O_2 component in the AO beam and N_2 effect in sub-LEO, a new system was developed.

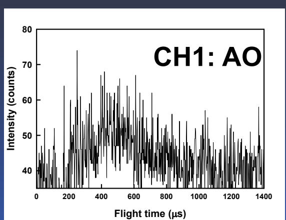
- *Low-cost*
- *Less space*
- *Accuracy of Ar flux measurement*

***One-nozzle, two-beam (ONTB) system** was developed.*

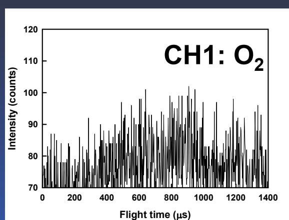
AO, O_2 and Ar



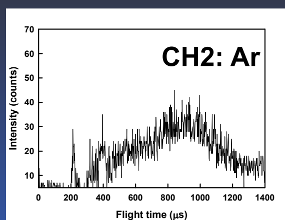
TOF distributions ONTB system



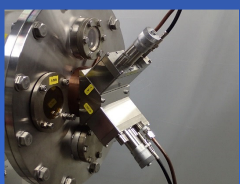
2.9 eV
2.0E+14 atoms/cm²/s



4.0 eV
5.6E+13 atoms/cm²/s



4.0 eV
6.6E+13 atoms/cm²/s



Dual-PSV configuration

Flux of each component was calculated by ….
PI-coated QCM for AO,
Area of flux-weighted TOF spectra for O_2 and Ar with relative ionization cross-sections.

Sample: PI-coated QCM
Conditions: room temperature, normal incidence

Kapton erosion yield (Ey)

The value of "Ey=3.0E-24 cm^3/atom" is firstly measured by

STS-8 (EOIM-1)

- Mission period: 30 September – 5 October 1982
- Altitude: 225 km
*- AO fluence: 3.5E+21 atoms/cm^2**
** calculated by MSIS ← N_2 effect was not considered*
MSIS calculated N_2 fraction is 33%
(Averaged value from 30/9/1982 to 5/10/1982 at 225 km)

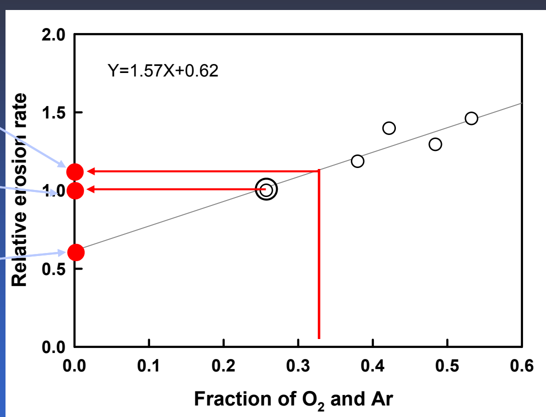
Ey has evaluated by some other missions as well:
STS-5, STS-46, LDEF….

Relative erosion rates

Ey=3E-24 cm^3/atom (STS-8)

Laser-detonation source

ISS orbit



- AO beam contains 27% O_2 in the original beam which is close to the environment at 225 km (33% N_2) !
- Kapton-equivalent AO fluence at ISS orbit may be underestimated !

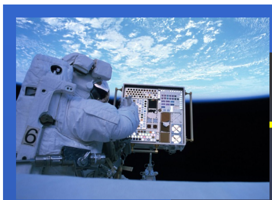
AO fluences, calculated vs. measured

Mission	Year	Platform	Atomic oxygen fluence (atoms/cm^2)		
			MSIS prediction	Kapton-equiv.	ratio
EOIM-3	1986	STS-46	2.10E+20	2.40E+20	1.14
JEM/MPAC&SEED	2010	ISS	1.40E+21	5.90E+20*	0.42
MEDET	2008	ISS	2.30E+21	1.70E+21	0.71

**Vespel-equivalent fluence*

AO fluence measured by MEDET and JEM-SEED missions are smaller than the MSIS-predicted values.

Possible reasons: (1) Shielding effect by ISS structures or STS?
(2) Ey at ISS orbit is smaller than 225 km?



AO fluences in MISSE-2

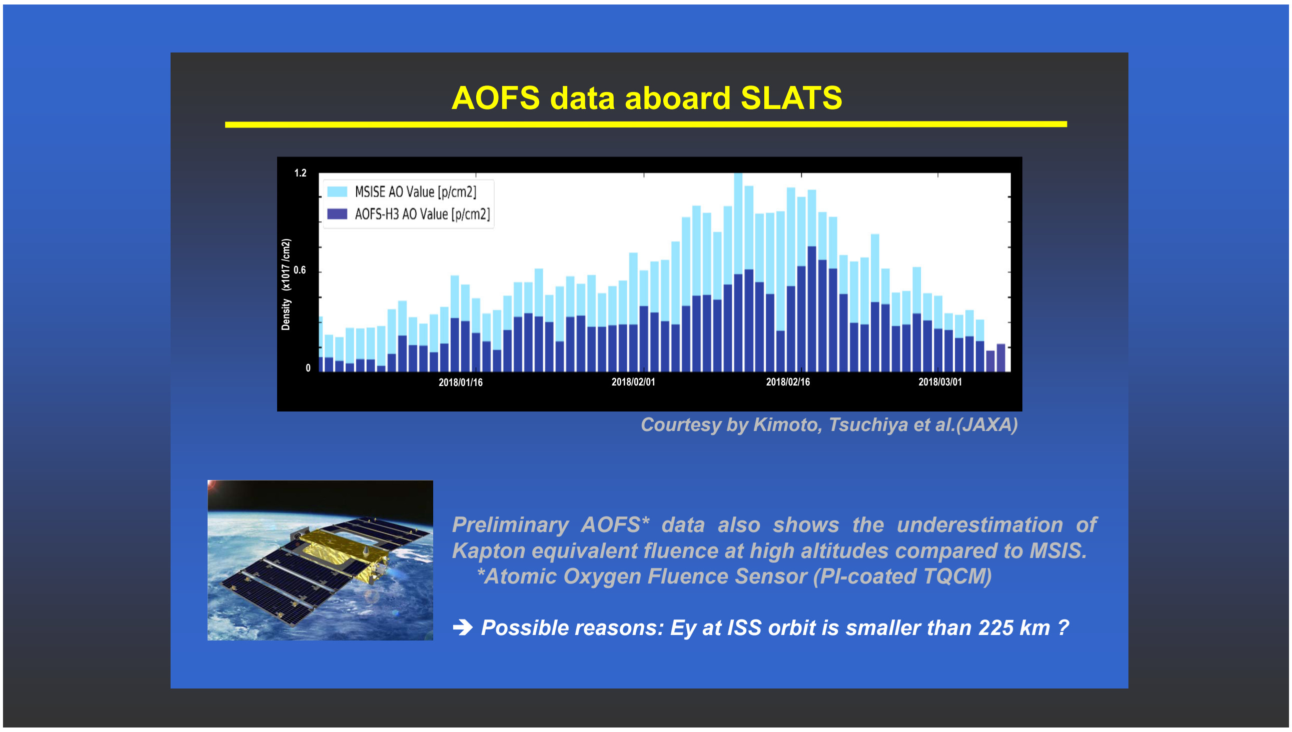
MISSE-2 data were provided by K. K. de Groh and B. A. Banks

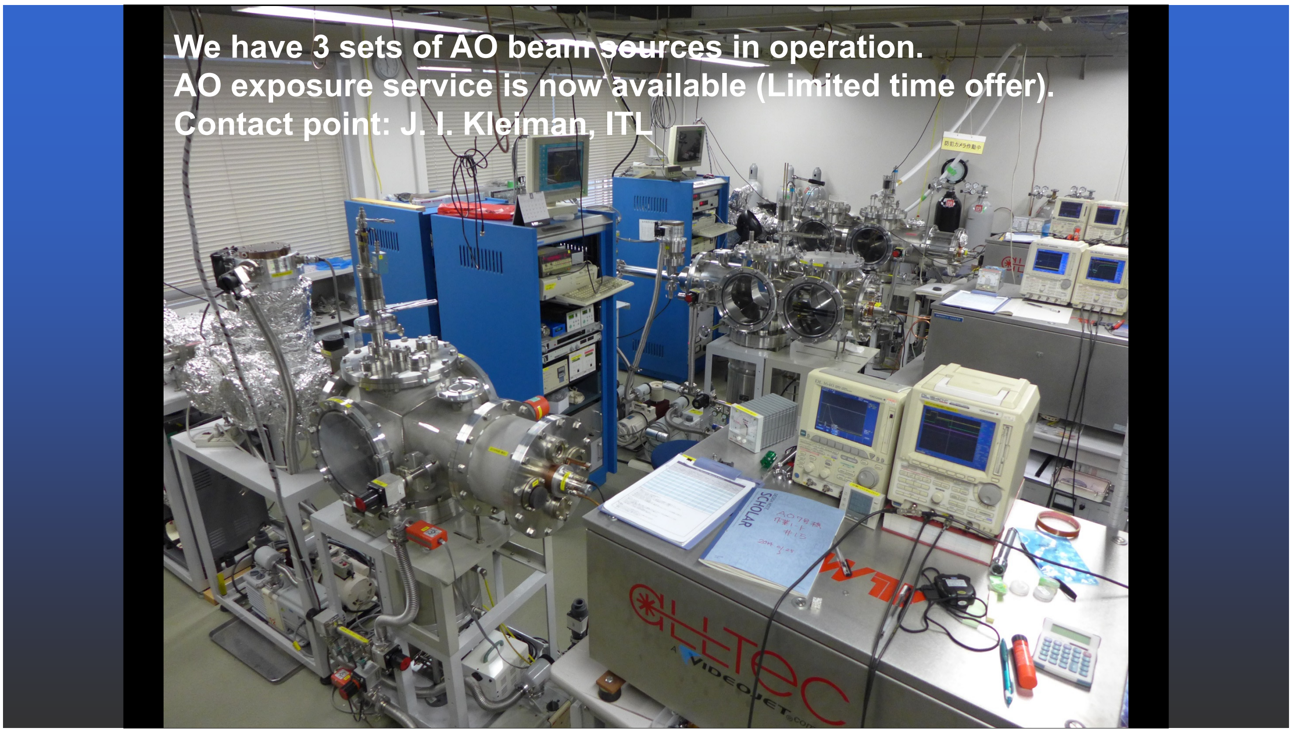
Location	Atomic oxygen fluence (atoms/cm^2)		
	Calculated*	Kapton-equiv.	ratio
Ram-side, near airlock	9.90E+21	6.5 - 6.8E+21	0.66 - 0.69
Ram-side, away from airlock	9.90E+21	8.5 - 9.1E+21	0.86 - 0.92
Wake-side	2.50E+19	1.67 - 1.99E+20	6.68 -7.96

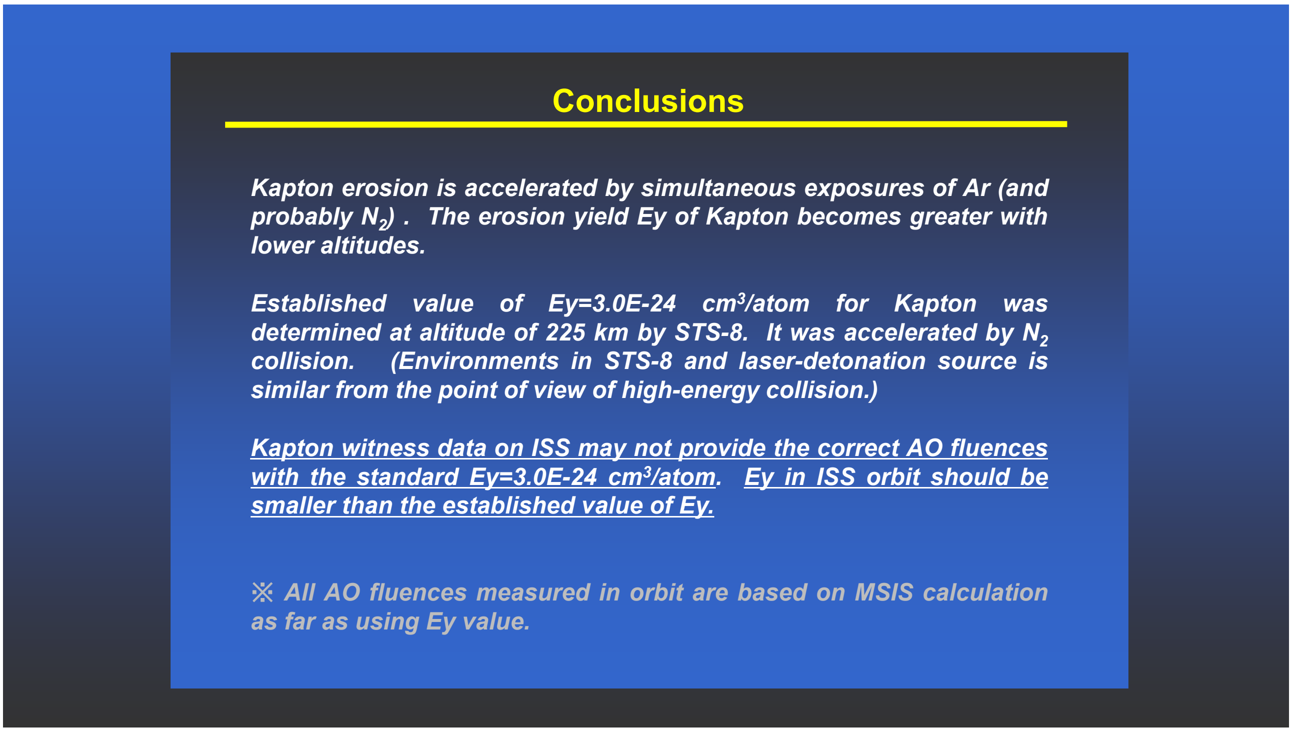
**Solar activity, ISS attitude and altitude and shielding effect by docked orbiter are taken into consideration in the calculation (by Gary Pippin).*
**1.24E+22 if above mentioned corrections were not applied on Ram-side.*

Possible reasons: (1) Complex nature of modeling for shielding
(2) Ey at ISS orbit is smaller than 225 km?

➔ To avoid uncertainty, real-time measurement on small satellites is beneficial…..Expecting the SLATS/AOFS data


AOFS data aboard SLATS
MSISE AO Value [p/cm2]
AOFS-H3 AO Value [p/cm2]
Density (x1017 /cm2)
1.2
0.6
0
2018/01/16
2018/02/01
2018/02/16
2018/03/01
Courtesy by Kimoto, Tsuchiya et al.(JAXA)
Preliminary AOFS* data also shows the underestimation of Kapton equivalent fluence at high altitudes compared to MSIS.
*Atomic Oxygen Fluence Sensor (PI-coated TQCM)
➔ Possible reasons: Ey at ISS orbit is smaller than 225 km ?


We have 3 sets of AO beam sources in operation.
AO exposure service is now available (Limited time offer).
Contact point: J. I. Kleiman, ITL


Conclusions
Kapton erosion is accelerated by simultaneous exposures of Ar (and probably N2) . The erosion yield Ey of Kapton becomes greater with lower altitudes.
Established value of Ey=3.0E-24 cm3/atom for Kapton was determined at altitude of 225 km by STS-8. It was accelerated by N2 collision. (Environments in STS-8 and laser-detonation source is similar from the point of view of high-energy collision.)
Kapton witness data on ISS may not provide the correct AO fluences with the standard Ey=3.0E-24 cm3/atom. Ey in ISS orbit should be smaller than the established value of Ey.
※ All AO fluences measured in orbit are based on MSIS calculation as far as using Ey value.