Second Generation Multi-Gas Monitor for ISS and Orion

The Anomaly Gas Analyzer

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Outline

- 1st generation MGM flight experiment history
- Advantages of TDLS based air monitors
- Pictorial history of monitor development
- Anomaly Gas Analyzer for Orion and ISS
- Requirements and brief operations concept
- Difficult compounds: ammonia, acid gases, hydrazine
- AGA calibration/testing at JSC
- Flight hardware and certification schedule
- Future Directions

Multi-Gas Monitor (MGM) Tech Demo

Ammonia	5 – 20,000 ppm		Mass	2.5 kg
Carbon Dioxide	250 – 30,000 ppm		Power	2.6 W
Oxygen	4 – 36%		Volume	3.4 L
Water Vapor	500 – 50,000 ppm		Data storage	2 GB

MGM operating on battery power on ISS

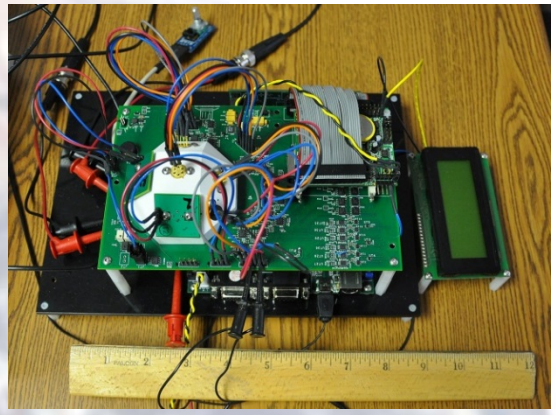
MGM Tech Demo Timeline

Date	Event
Jul 22-30, 2013	MGM calibrated at NASA-JSC
Nov 7, 2013	MGM launched on 37 Soyuz
Feb 3, 2014	Activation and check out on ISS
Feb 11, 2014	SPHERES CO_2 thruster unplanned “challenge”
Jul 25, 2014	Ammonia inhalant test conducted by crewmember
Dec 15, 2014	Manual reset of MGM by crewmember
Jan 14, 2015	Thermal control ammonia false alarm
Jan 16-17, 2015	SPHERES CO_2 thruster unplanned “challenge”
Aug 25-26, 2015	Deployed on battery power to Node 3
Aug 28-Sep 28, 2015	Deployed on 28V EXPRESS rack power to US Lab
Sep 28, 2015 onward	MGM reinstalled in JEM Nanoracks Frame (Nose out)
Oct 1, 2015 to Jan 1, 2016	Sporadic data takes; MGM display failed late November
Mar 10, 2016	Crew power cycled MGM & photographed display
Jan 19, 2017	Rack/MGM powered off GMT 19 at 14:15
Mar 19, 2017	MGM returns to Earth on SpaceX 10 Dragon capsule
April 2017	Post flight inspection and data analysis at JSC
July 2017	MGM Display replaced at Vista Photonics
Oct 2017	Post flight Calibration check at NASA-JSC

Tunable Diode Laser Spectroscopy

- High tech optical system but can be implemented in small rugged package
- New low power diode lasers in mid infrared provide versatility in a battery powered hand-held package
- Specificity: Each gas has own laser at exactly optimal wavelength
- Unprecedented dynamic range
- Various optical geometries to address the concentration ranges of interest
- Calibration appears to be stable for YEARS! No need for cal gas!

Pictorial History of MGM/AGA Development



2011 OLGA sensor v1.0

2011 OLGA v2.0 Lab Unit

2012 OLGA v3.0 Ground Demo

2013 MGM ISS Tech Demo v4.0

2016 Laser Ammonia Monitor

2015 Blue MGM for sea trials v5.0

2017 AGA prototype

Objectives of the AGA Project

- Replace obsolete hand-held hardware on ISS
- Eliminate Draeger tubes for ammonia leak response
- Improve specificity, dynamic range, calibration life
- Combine multiple ISS units into a single hand-held device
- Long-life units will reduce ground support costs
- Meet both ISS and Orion requirements

AGA Requirements

Parameter	Measurement Range	Display Update Frequency Nom/Emer	90% Resp (min)	Accuracy	Display Resolution
Total Pressure	7 - 16 psia	2 sec		± 0.1 psia	0.05 psia
CO	5 - 1000 ppm	2 sec	1	± 10% ≥ 55 ppm ± 5 ppm < 55 ppm	1 ppm ≤ 250 ppm 10 ppm > 250 ppm
HCN	2 - 50 ppm	2 sec	2	± 25% ≥ 5 ppm ± 1 ppm < 5 ppm	1 ppm
HF	2 - 50 ppm	2 sec	2	± 25% ≥ 5 ppm ± 1 ppm < 5 ppm	1 ppm
HCl	2 - 50 ppm	2 sec	2	± 25% ≥ 5 ppm ± 1 ppm < 5 ppm	1 ppm
CO2	0.3 - 21 mmHg (395 - 27600ppm@ 760)	2 sec	1	± 10% ≥ 0.8 mmHg ± 0.2 mmHg < 0.8 mmHg	0.1 mmHg
O2	14 - 50%	2 sec	1	± 1% (absolute) ≤ 25% ± 2% (absolute) > 25%	0.1%
NH3	10 - 30,000 ppm	2 sec	2	± 25% > 150 ppm ± 10% 20 - 150 ppm ± 20% < 20 ppm	1 ppm ≤ 150 ppm 10ppm > 150-1000 ppm 100 ppm > 1000 ppm
N2H4	1 - 10 ppm	2 sec	2	± 2 ppm	1 ppm

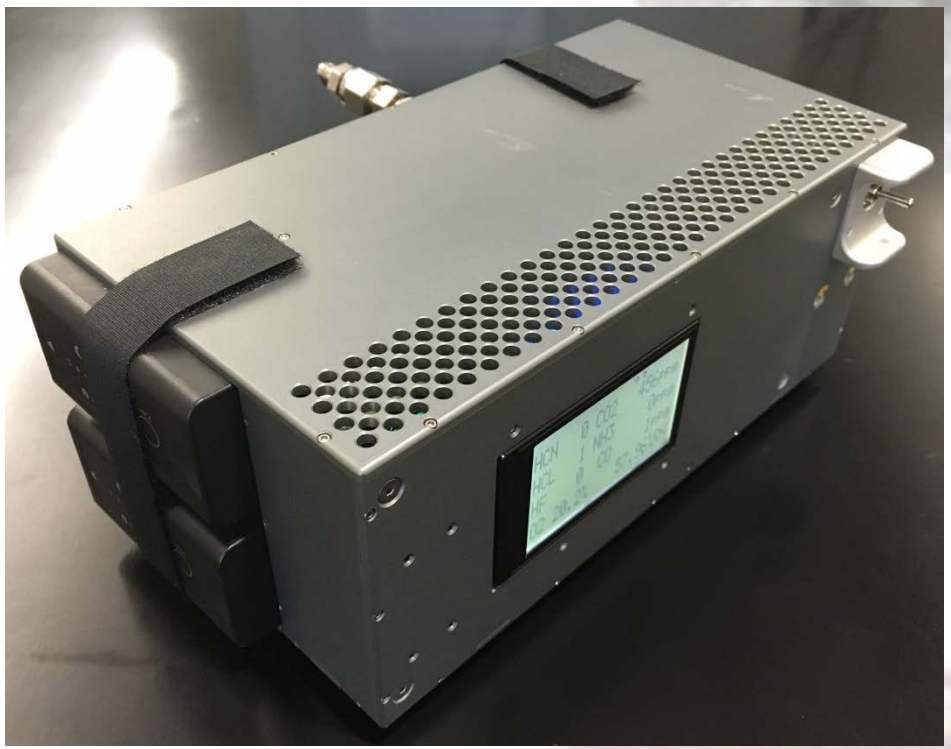
Difficult Compounds

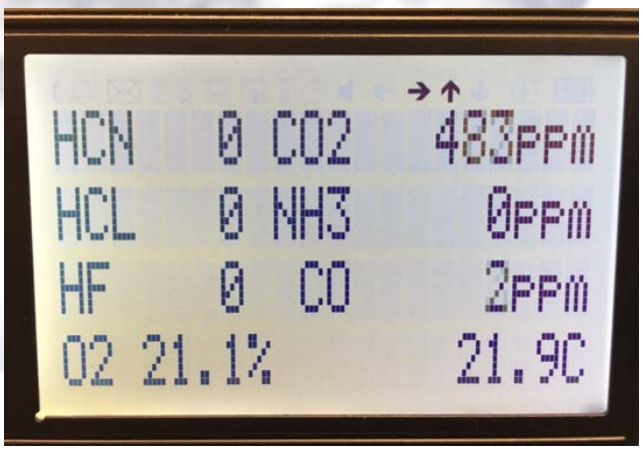
- Ammonia --- sticky, very wide dynamic range required
- HCl, HF --- acid gases, “etchant”
- Hydrazine --- hypergolic thruster chemical, reactive
- Water vapor---tends to complicate above measurements

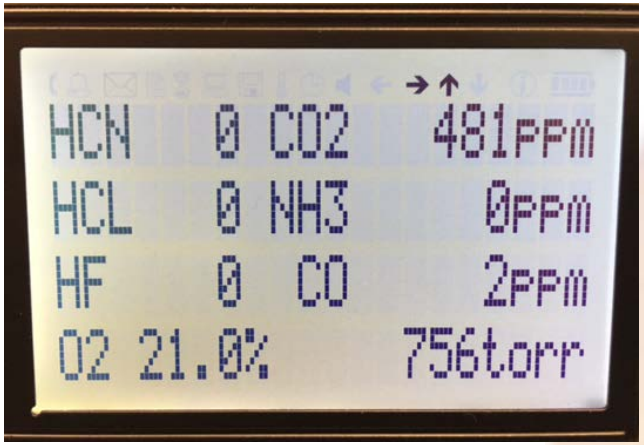
- All gases available in compressed gas cylinder standards except hydrazine (and water)

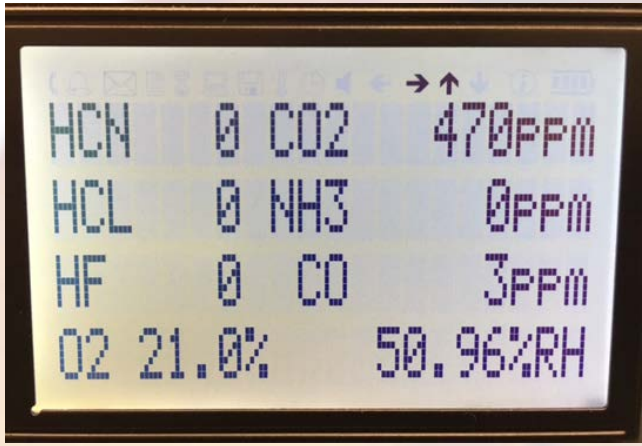
AGA Prototype

- Accepts up to 4 Canon camcorder batteries
- Mass: 2.3 kg
- Dimensions: 21.6 cm x 11.4 cm x 9.2 cm (2.3L)
- One toggle operation
- Gas interface for rapid calibration

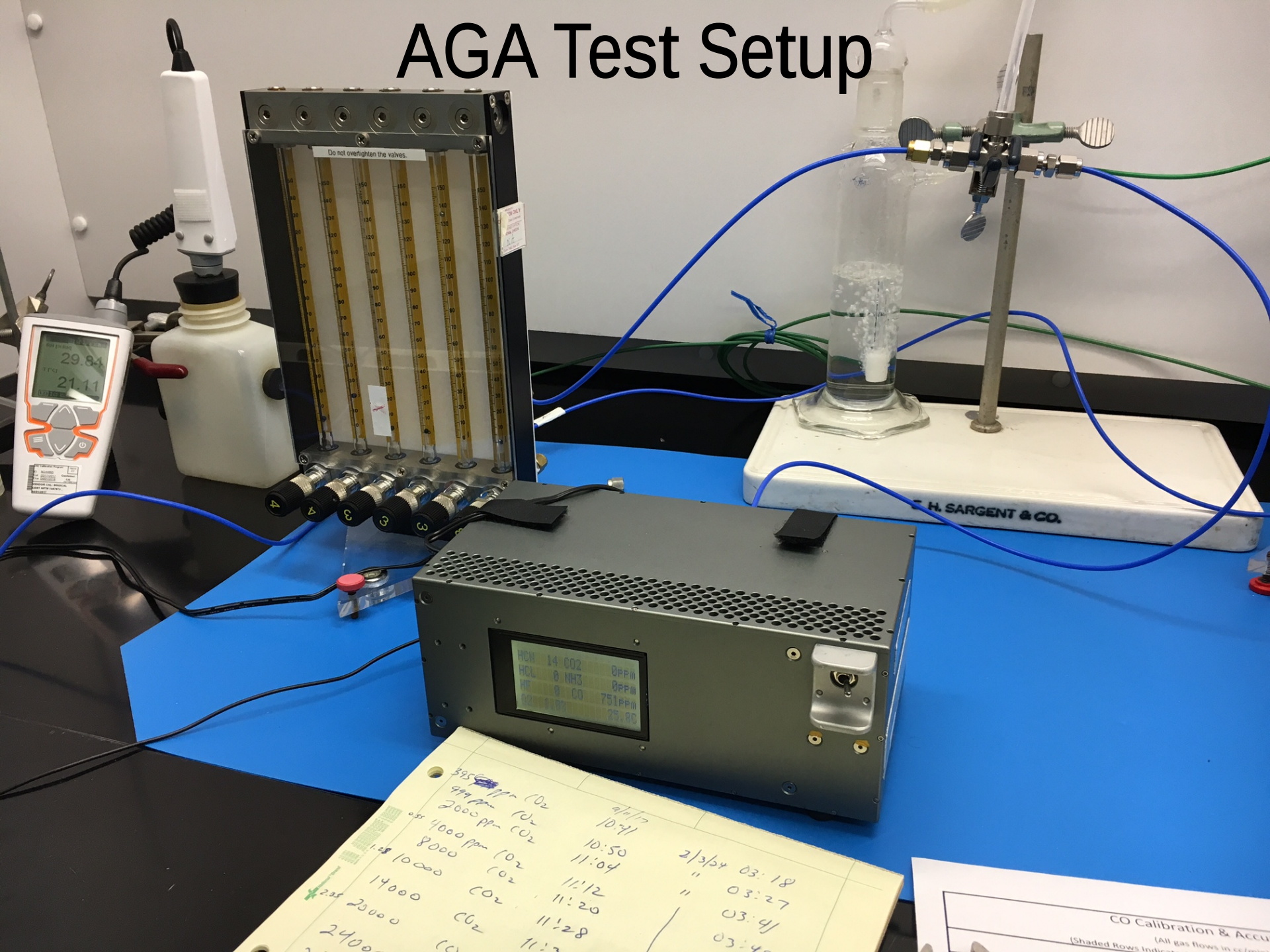




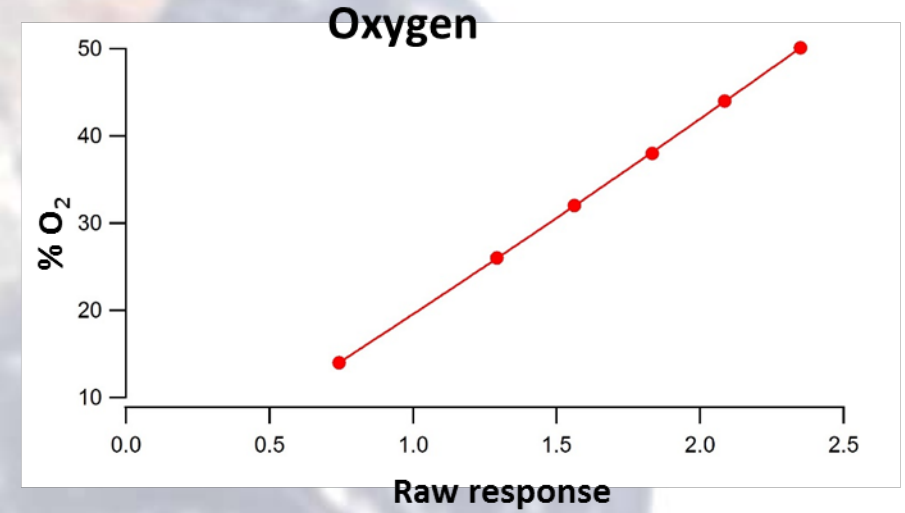


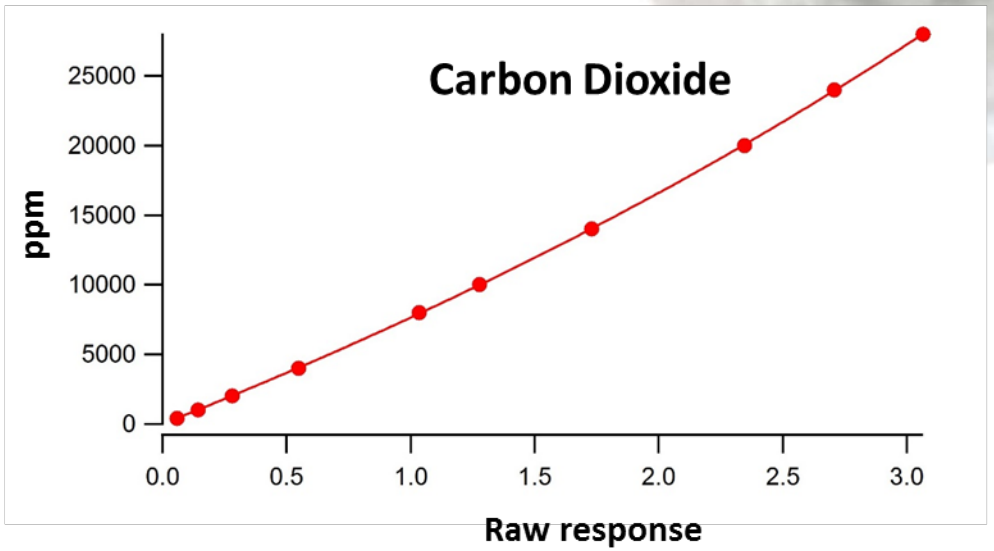


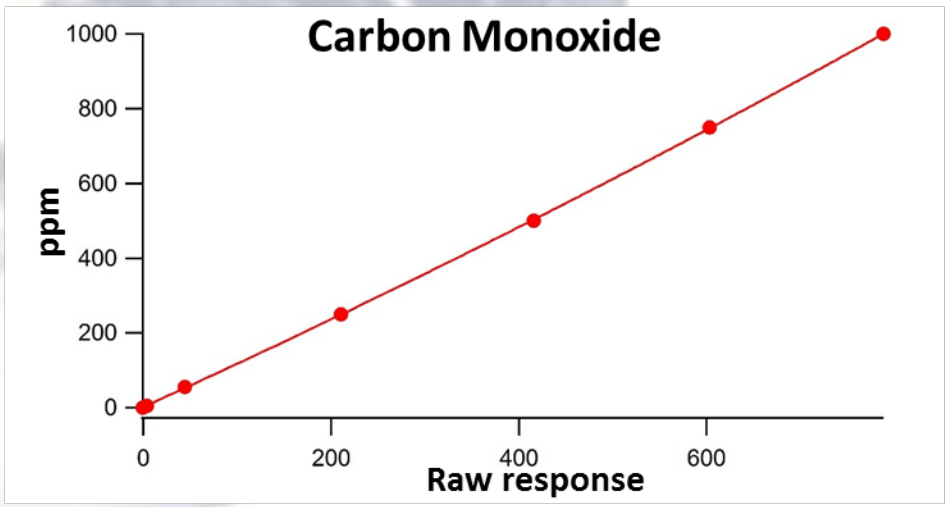
AGA Test Setup

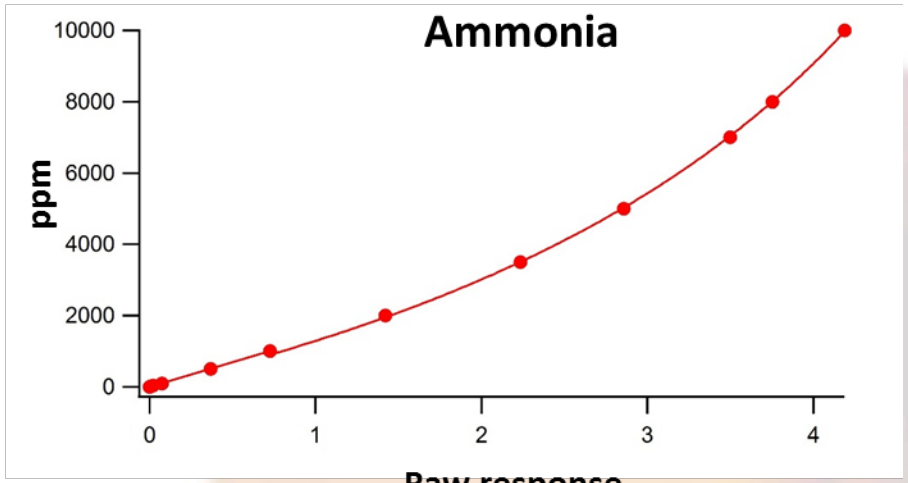


AGA Calibration Results



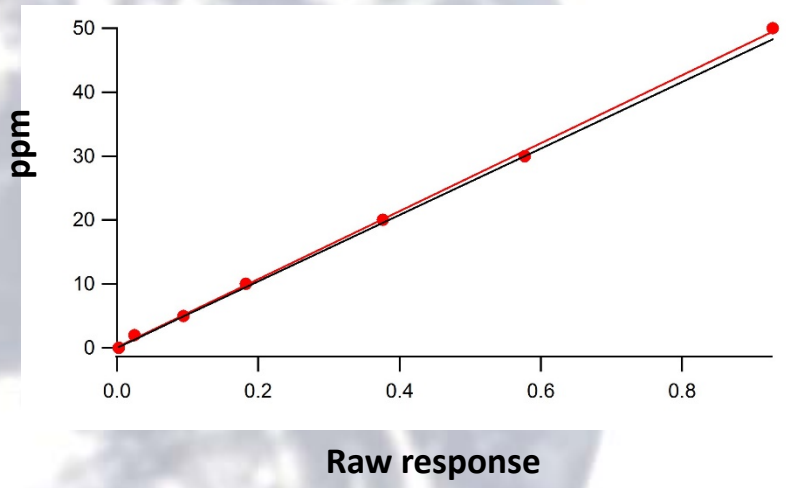




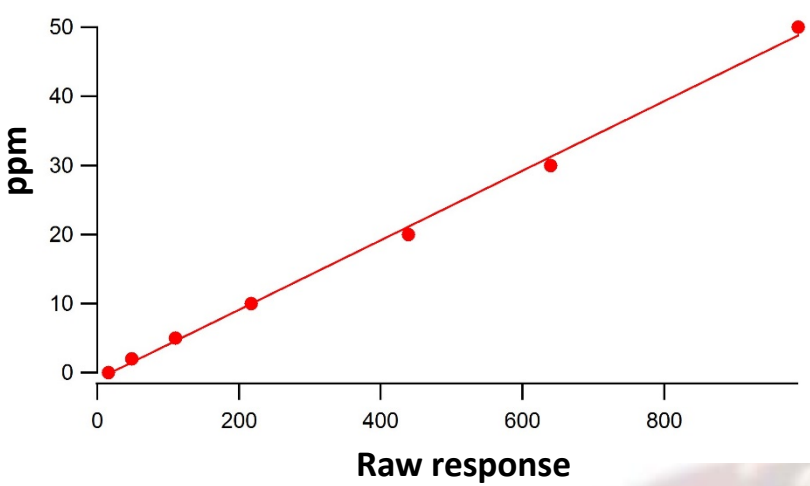


Calibration Results cont'd

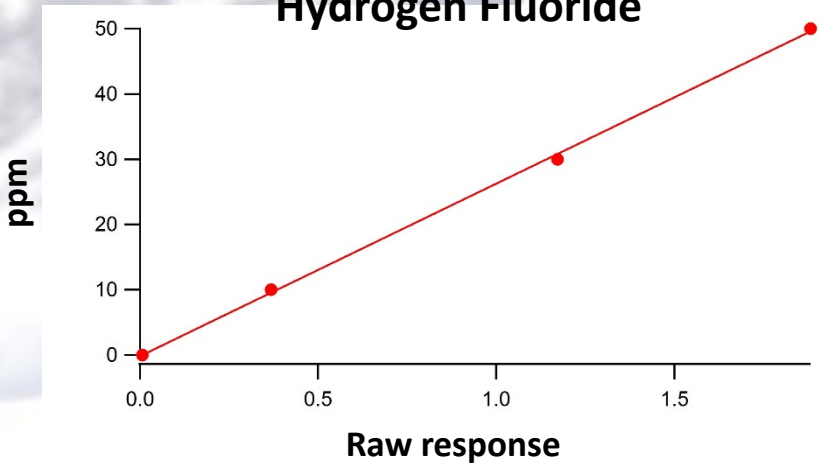
Hydrogen Chloride

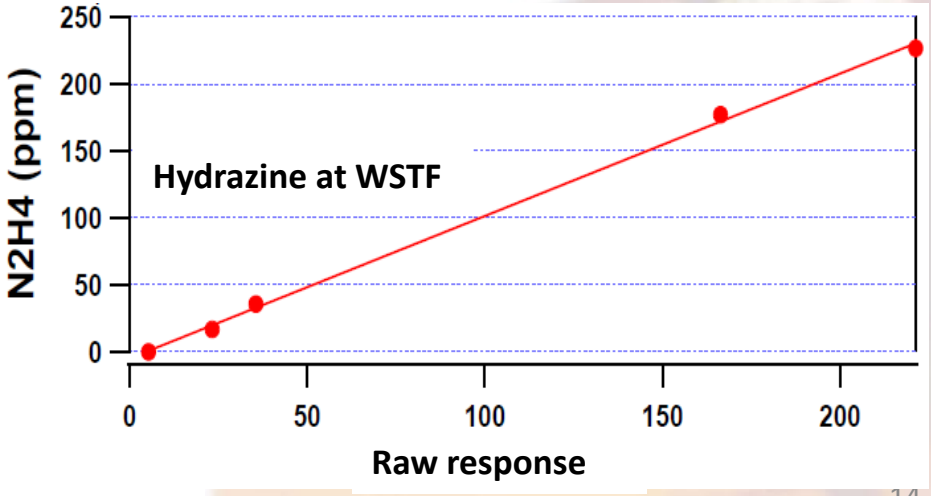


Hydrogen Cyanide

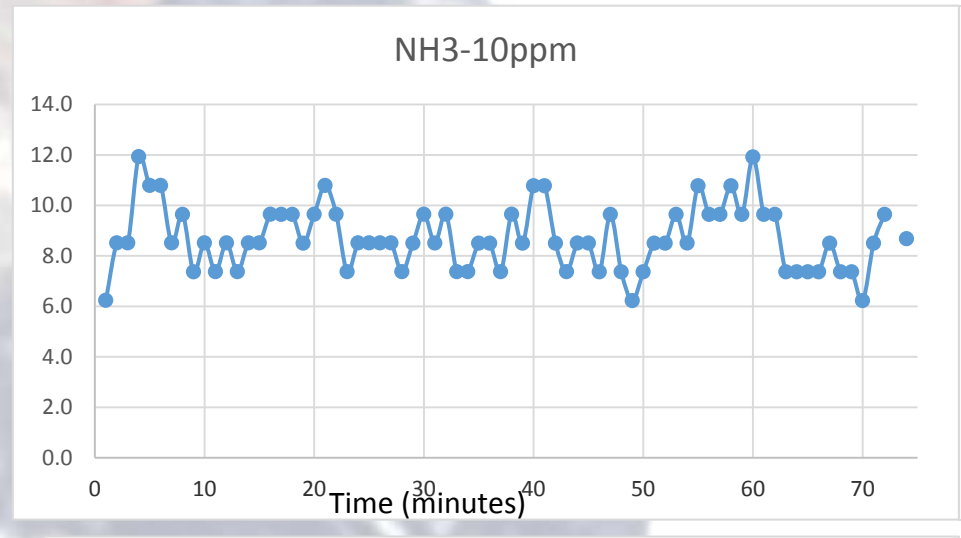


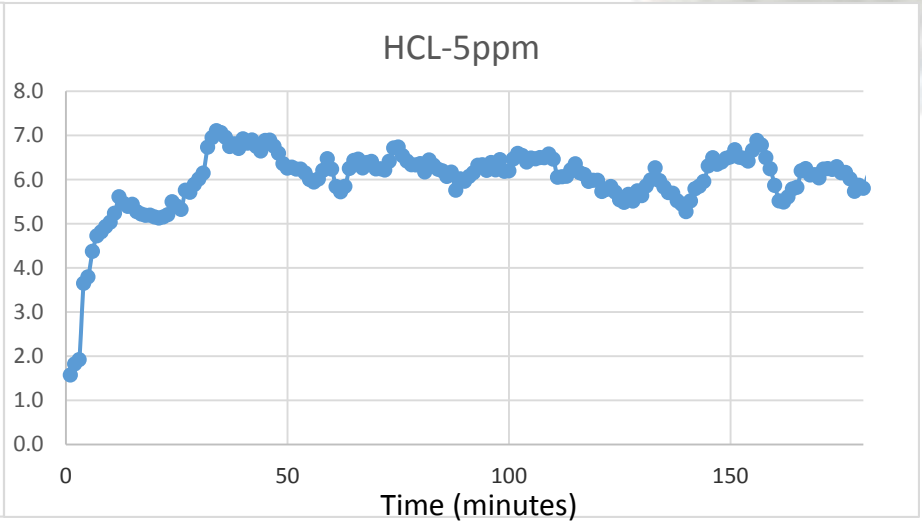
Hydrogen Fluoride

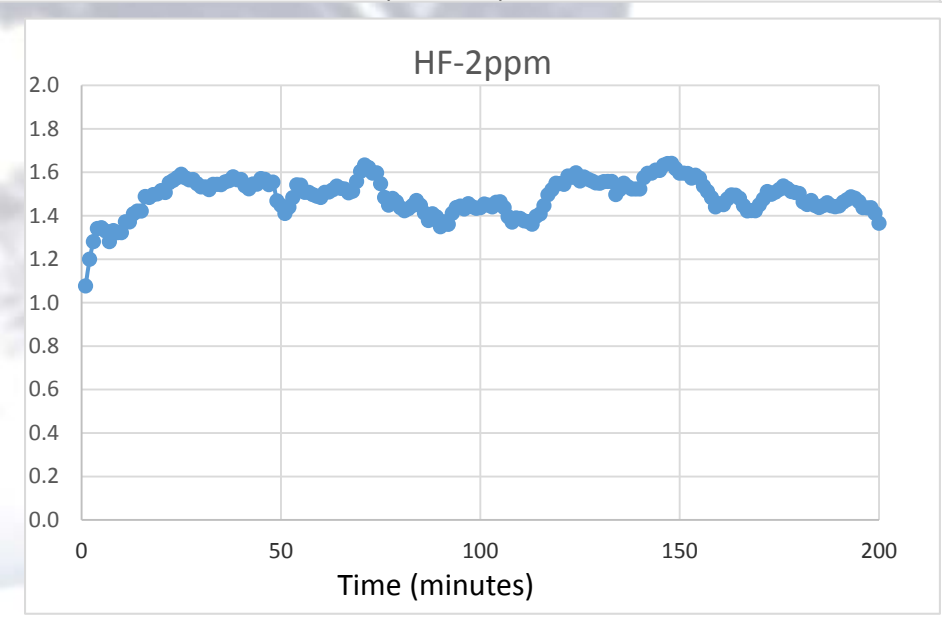


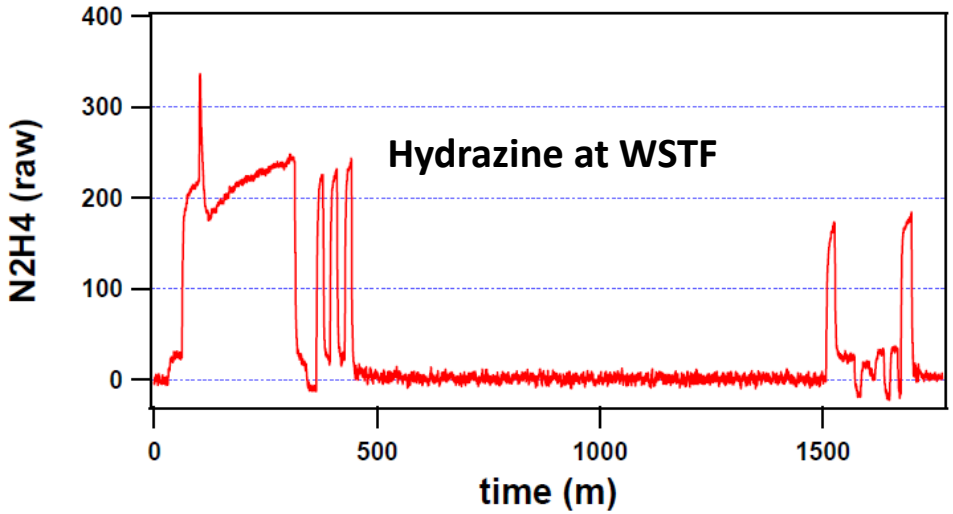


The “Sticky” Gases





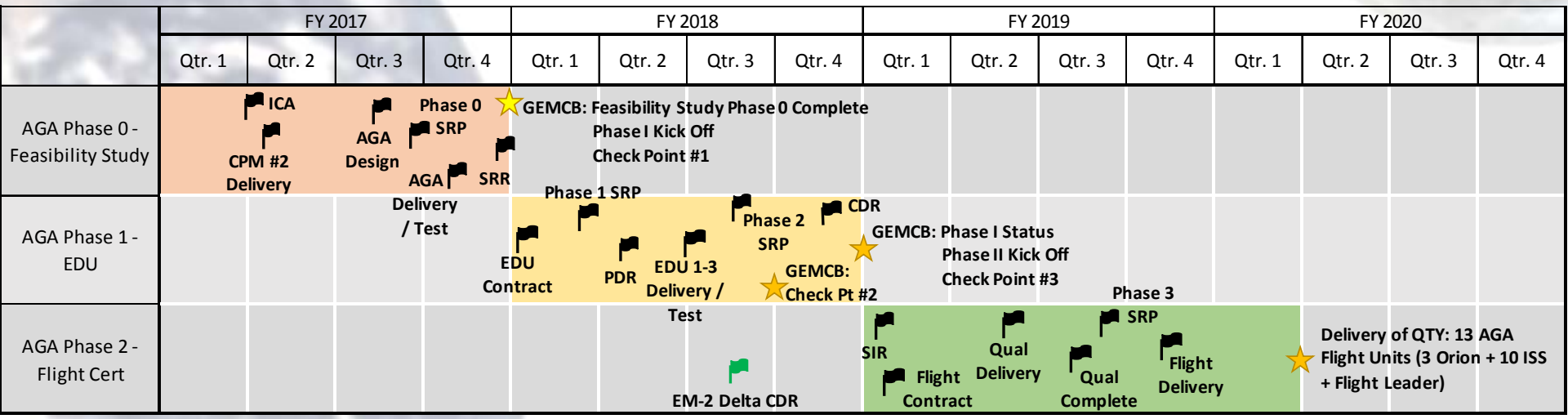




AGA Calibration Verification

	AMMONIA			
Std Conc (ppm)	**10**	**30**	**1011**	**10000**
AGA Conc (ppm)	9	28	1014	10011
Requirement (ppm)	±2	±3	±252	±2500
	OXYGEN			
Std Conc (%)	**14.0**	**32.0**	**50.1**	
AGA Conc (%)	14.1	32.6	50.2	
Requirement (% absolute)	±1	±2	±2	
	CARBON DIOXIDE			
Std Conc (ppm)	**395**	**8,000**	**14,000**	**28,000**
Std Conc (mmHg)	**0.3**	**6.1**	**10.6**	**21.3**
AGA Conc (mmHg)	0.33	6.1	10.4	20.7
Requirement mmHg)	±0.2	±0.6	±1.6	±2.8
	CARBON MONOXIDE			
Std Conc (ppm)	**5**	**55**	**500**	**1000**
AGA Conc (ppm)	8	55	500	999
Requirement (ppm)	±5	±5	±50	±100
	HYDROGEN CYANIDE			
Std Conc (ppm)	**2**	**5**	**20**	**50**
AGA Conc (ppm)	1	4	21	49
Requirement (ppm)	±1	±1.25	±5	±12.5
	HYDROGEN FLUORIDE			
Std Conc (ppm)	**2**	**5**	**20**	**50**
AGA Conc (ppm)	2	4	22	55
Requirement (ppm)	± 1	± 1.25	±5	±12.5
	HYDROGEN CHLORIDE			
Std Conc (ppm)	2	5	20	50
AGA Conc (ppm)	1	6	22	55
Requirement (ppm)	± 1	± 1.25	±5	±12.5
Meets Requirement				

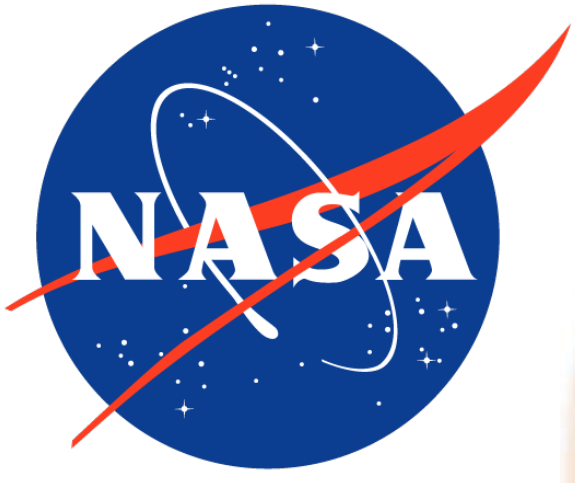
Flight Hardware Build/Cert Schedule



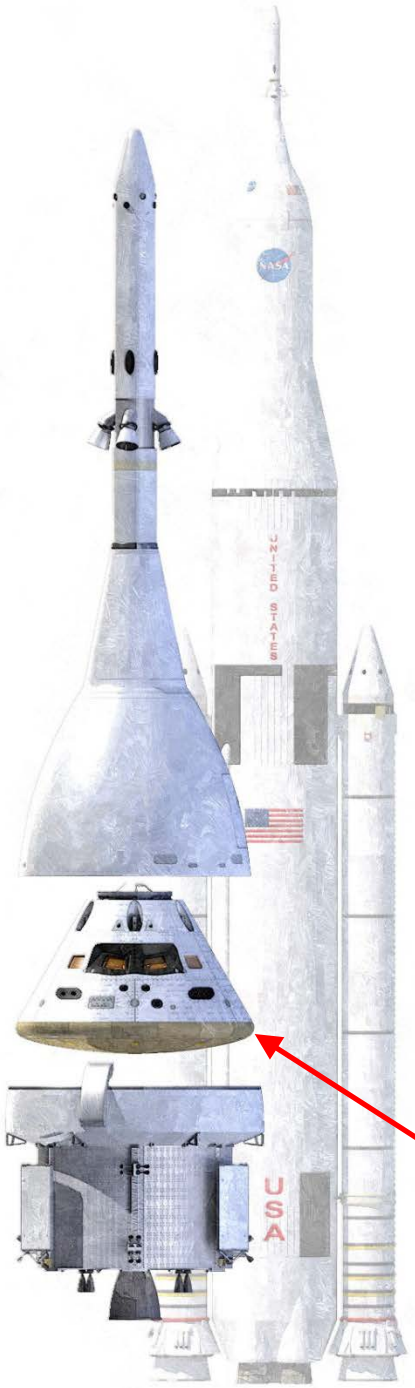
Hardware Delivery Dates	Development Hardware	Qualification Hardware	Training Units	Flight Units
AGA	1 Prototype 3 EDUs (Mar 18)	1 Qual Unit (Jan/Feb 19)	1 Qual Unit 3 EDUs used as Trainers	Orion 3 Flight (FY20) ISS 10 Flight Units (FY20)

Acknowledgments

- Steve Beck and Samantha Garza of KBRwyle conducted many of the laboratory tests
- MGM was funded by the ISS Program
- AGA is funded jointly by Orion and ISS Programs



Conclusion & Future Directions



- AGA flight hardware build and cert is a 2 year effort
- Plan to demonstrate an AGA at the next SAMAP
- First flight of AGA on Orion ~
- First flight of AGA on ISS ~
- Because of high reliability and long calibration interval, we recommend TDLS based monitors be considered for submarines
- Sea trials of AGA would be a logical follow-on to the MGM sea trial that is currently underway

Orion capsule