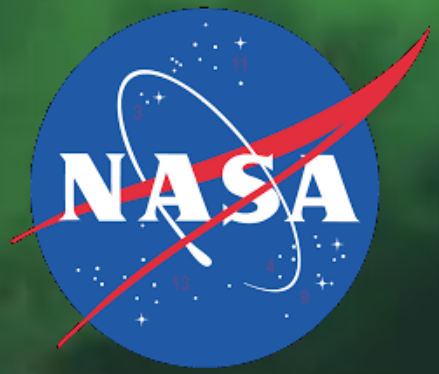
GRC Remote Sensing Campaign of Harmful Algal Blooms 2017-2019



Presented to:
HAB Algorithm Development Meeting
NASA Glenn Research Center

Presented by:
Roger Tokars
Optical Systems Research Engineer
NASA Glenn Research Center

Slides Overview

GRC Remote Sensing Campaign of Harmful Algal Blooms 2017-2019

by Roger Tokars

- Campaign Summary
- Aircraft install
- HSI versions and specifications
- Flight/HSI issues

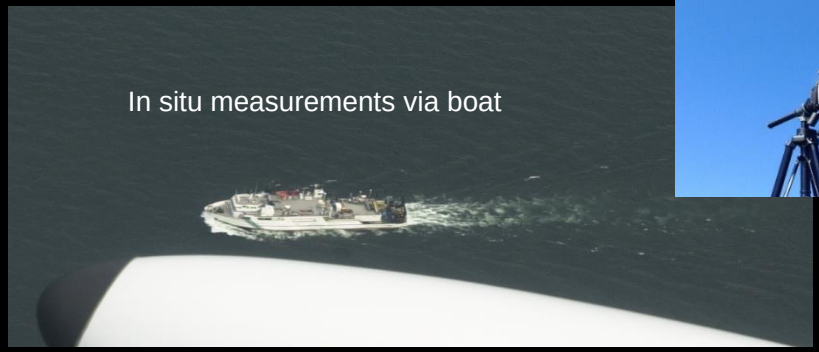
Campaign Summary

Remote Sensing of Harmful Algal Blooms in the Great Lakes Region

A Leader in Airborne Hyperspectral Imaging
- A focus on Western Lake Erie.
- Monitoring HABs for local water treatment operators
- Validating future HAB sensing technologies

GRC Operations past and present
- 2014 Expanded from 4 to 14 NASA flights to meet demand
- 2015 26 NASA flights at about 80 flight hours
- 2016 17 NASA flights.
- 2017 13 NASA Flights at about 31 flight hours.
- 2018 13 NASA Flights at about 32 flight hours.
- 2019 9 NASA Flights at about 26 flight hours.

Research partners also conduct water sampling and ground optical measurements
- NOAA GLERL
- University of Toledo
- Kent State University
- Michigan Tech Research Institute
- Bowling Green State University
- University of Cincinnati
- Naval Research Lab
- University of Alabama



HAB information provided by remote sensing and water sampling can provide for early warning to ensure proper water treatment and shutoff avoidance

Hyperspectral Imager on Twin Otter (2015, 2017, 2018, 2019)

Installation from 2015

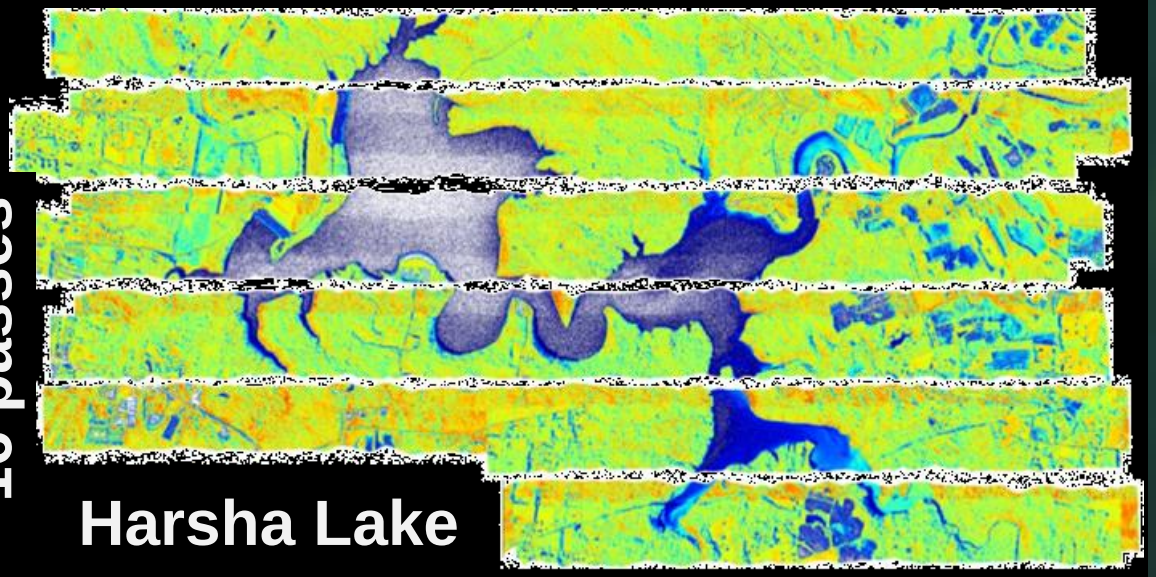
HSI 2.0

Flown on T-34, Twin Otter, and Viking S3 (2007-2017)

Installation on Viking S3

GRC HSI2.0	
Wavelength range	400-900 nm
Optical spectral resolution	2.5 nm
Spectral sampling resolution	1 nm
Optical throughput	f/2.0
Digitization bit depth	14 bit
Maximum spatial resolution along travel direction (imager rate limited)	1 m
Field of view (angle)	12.4° with 23 mm focal length lens
Field of view (swath width)	2102' @ 10k' altitude
Imaging rate	25 frames per sec
Camera pixels	658 x 496 (0.3 MP)
Camera interface	USB 2.0
System mass	3.7 kg
Volume	12 cm x 15 cm x 18 cm
Power consumption	35 W

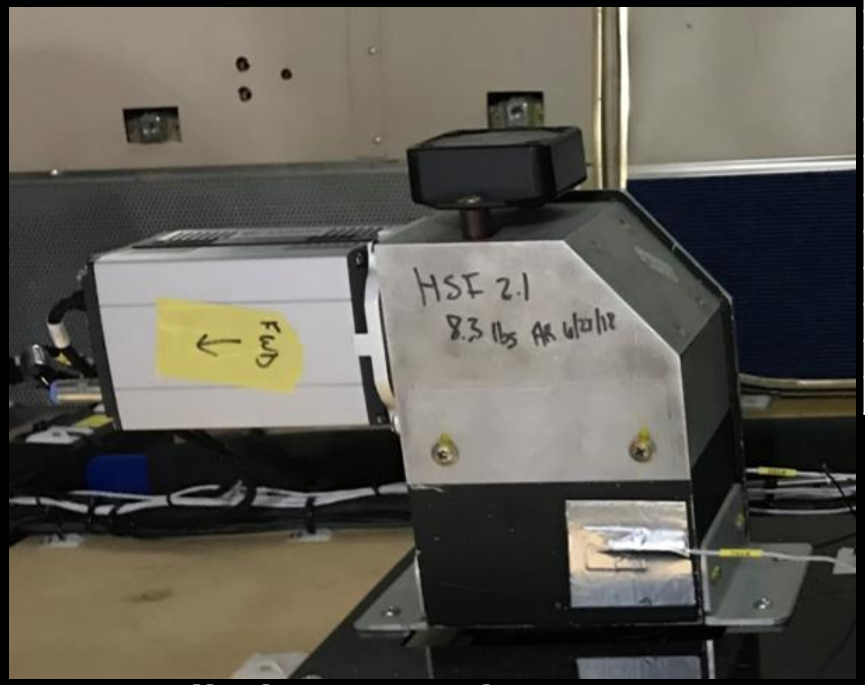
Legacy unit: flown since 2007 on several NASA aircraft



Harsha Lake

HSI 2.1

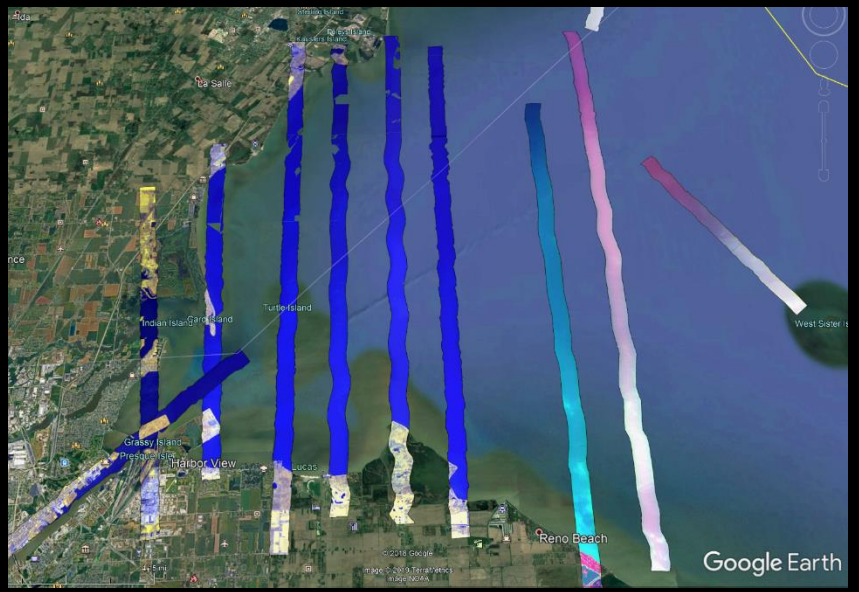
Flown Twin Otter (2018)



Installation on Twin Otter with temp sensors

GRC HSI2.1	
Wavelength range	400-900 nm
Spectral sampling resolution	1 nm
Digitization bit depth	16 bit
Maximum spatial resolution along travel direction (imager rate limited)	1 m
Field of view	16.6° with 8mm focal length lens
Field of view (swath width)	2917' @ 10k' altitude
Imaging rate	30 frames per sec (adjustable)
Camera pixels	2560 x 2160 (960 cropped)
Camera interface	USB 3.0
System mass	≈3.8kg
Volume	9 cm x 9 cm 33 cm
Power consumption	30 W, 12VDC, 5 A inrush

Upgrade: New hi-resolution Zyla camera with narrow field of view.



High Resolution passes over Western Lake Erie, Sept 17, 2018

HSI 3.0

Flown on Twin Otter and Viking S3 (2016)

Installation on Viking S3

GRC HSI3.0	
Wavelength range	350-1000 nm
Spectral sampling resolution	2 nm
Signal-to-noise ratio	250:1 at 600 nm @ white body 9500' no atmospheric correction
Digitization bit depth	14 bit
Maximum spatial resolution along travel direction (imager rate limited)	1 m
Field of view	72° with 8mm focal length lens
Field of view (swath width)	14531' @ 10k' altitude
Imaging rate	60 frames per sec
Camera pixels	1032 x 1032kg
Camera interface	Gig Ethernet
System mass	1.42 kg
Volume	8 cm x 9 cm 28 cm
Power consumption	6 W, 12VDC, 1.5 A inrush

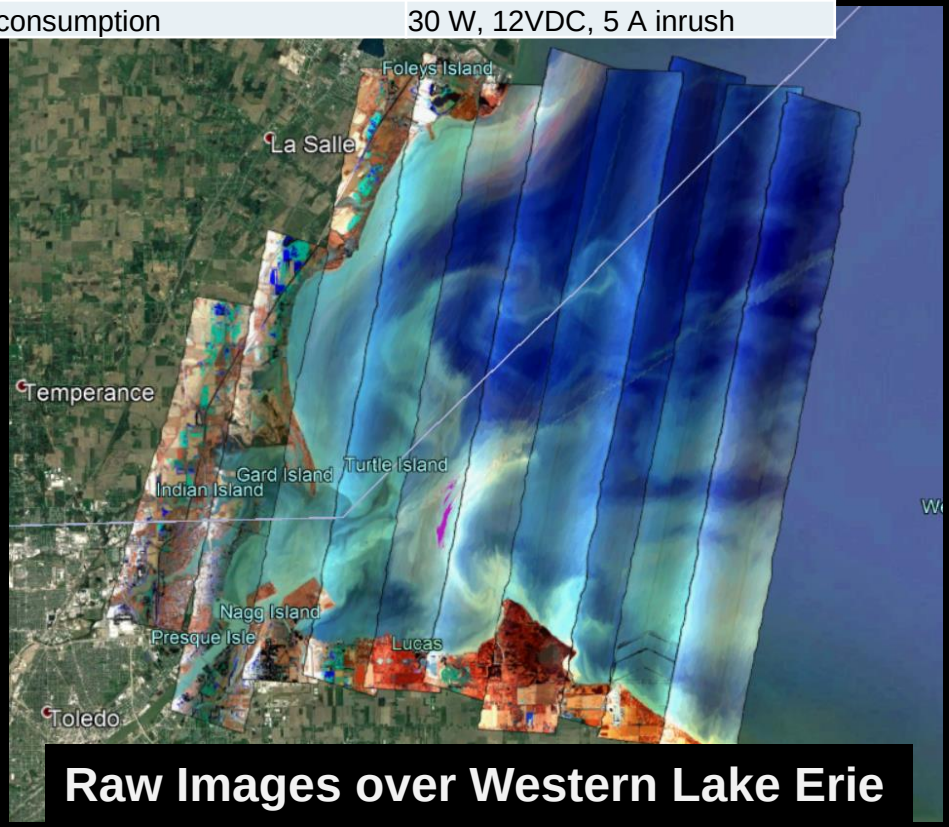
Advantages: 6x the field of view, 4x the camera pixels, twice the frame rate, more reliable GigE interface

HSI 3.1

Flown on Twin Otter (2017)

Installation on Twin Otter with HSI2 and INS

GRC HSI3.1	
Wavelength range	400-900 nm
Spectral sampling resolution	1 nm
Digitization bit depth	16 bit
Maximum spatial resolution along travel direction (imager rate limited)	1 m
Field of view	72° with 8mm focal length lens
Field of view (swath width)	14531' @ 10k' altitude
Imaging rate	30 frames per sec (adjustable)
Camera pixels	2560 x 2160 (5.5 MP)
Camera interface	USB 3.0
System mass	≈2.2kg
Volume	9 cm x 9 cm 33 cm
Power consumption	30 W, 12VDC, 5 A inrush



Raw Images over Western Lake Erie

Advantages: 6x the field of view, 17x the camera pixels, and utilizes low noise thermoelectric cooler.

HSI 3.2

Flown on Twin Otter (2018, 2019)

Installation on Twin Otter with INS and temp sensors

GRC HSI3.2	
Wavelength range	400-900 nm
Spectral sampling resolution	1 nm
Digitization bit depth	16 bit
Maximum spatial resolution along travel direction (imager rate limited)	1 m
Field of view	56° with 8mm focal length lens
Field of view (swath width)	10634' @ 10k' altitude
Imaging rate	30 frames per sec (adjustable)
Camera pixels	2560 x 2160 (960 cropped)
Camera interface	USB 3.0
System mass	≈2.2kg
Volume	9 cm x 9 cm 33 cm
Power consumption	30 W, 12VDC, 5 A inrush

Advantages: more consistent SNR, less vignetting

HSI 4

Flown on Altavian F6500 (2016)

HyDRUS 1 Payload (4 lbs)

GRC HSI4	
Wavelength range	350-950 nm
Spectral sampling resolution	2 nm
Digitization bit depth	12 bit
Maximum spatial resolution along travel direction (imager rate limited)	sub meter
Field of view	55° with 8mm FL
Field of view (swath width)	425' @ 400' altitude
Imaging rate	30 frames per sec
Camera pixels	1288 x 964
Camera interface	USB 3.0
System mass	0.4 kg
Volume	4 cm x 11.6 cm x 16.5 cm
Power consumption	3 W max, 5V USB

Google Earth Map

Overlaid HSI Data

UAV Flight Path

Installation on Altavian F6500

Advantages: 5x the field of view, 4x the camera pixels, USB 3.0 speeds, compact and lightweight design, cost effective

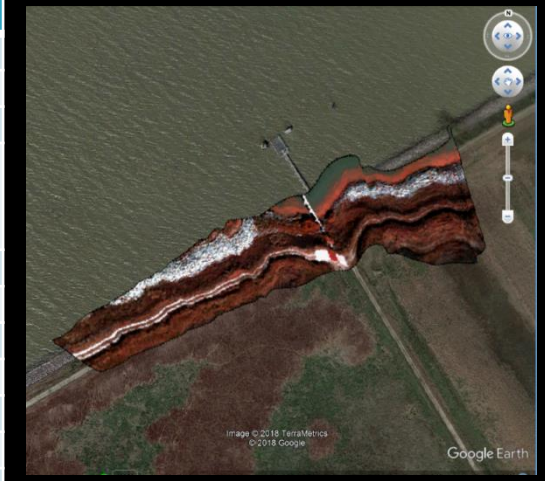
HSI 4

Flown on Altavian F7200 (2017 2018)

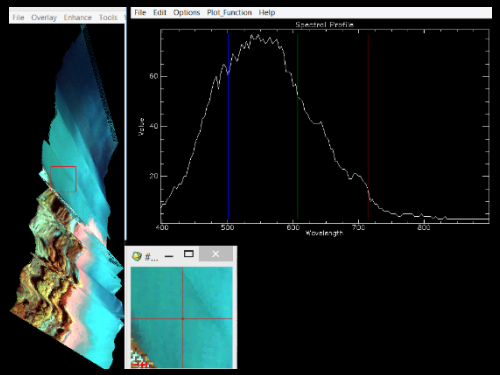
HyDRUS 2 Payload (4 lbs)

Installation on Altavian F7200

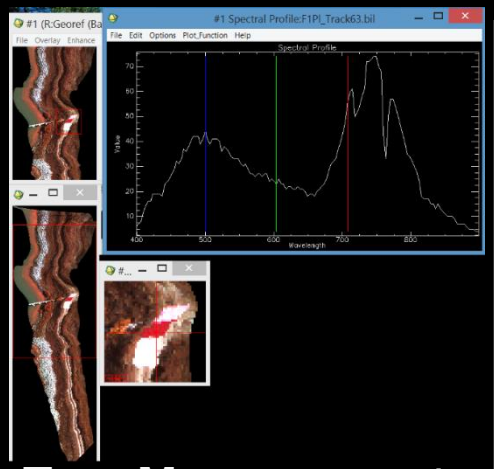
GRC HSI4	
Wavelength range	350-950 nm
Spectral sampling resolution	2 nm
Digitization bit depth	12 bit
Maximum spatial resolution along travel direction (imager rate limited)	sub meter
Field of view	55° with 8mm FL
Field of view (swath width)	425' @ 400' altitude
Imaging rate	30 frames per sec
Camera pixels	1288 x 964
Camera interface	USB 3.0
System mass	0.4 kg
Volume	4 cm x 11.6 cm x 16.5 cm
Power consumption	3 W max, 5V USB



Overlaid data



Water Measurement



Tarp Measurement

Advantages: 5x the field of view, 4x the camera pixels, USB 3.0 speeds, compact and lightweight design, cost effective

2017 Flight Schedule and Issues

Flew HSI2.0 and new HSI3.1

HSI2.0 old Toughbook CF-74 laptop
HSI3.1 new Toughbook CF-31 laptop

- Pre-flight: Upgraded HSI3.0 to HSI3.1 with new Zyla camera.
- Flight 1: June 21 first HSI3.1 flight — Western Lake Erie
- Flight 2: July 5
- Flight 3: July 17
- Flight 4: July 25
- Flight 5: July 26
- Flight 6: Aug 23
- Flight 7: Aug 25 — Harsha Lake
- Flight 8: Sept 11 — Western Lake Erie
- Flight 9: Sept 25
- Flight 10: Oct 2 — Harsha Lake
- Flight 11: Oct 3 — Western Lake Erie
- Flight 12: Oct 18
- Post-flight: Upgraded HSI2.0 to HSI2.1 with new Zyla camera.

2018 Flight Schedule and Issues

Flew new HSI2.1 and new HSI3.2

HSI2.1 new rack servo comp
HSI3.2 CF-31 laptop
(original install was opposite)

- Pre-flight: HSI3.1 upgraded to HSI3.2 with new frame and lenses.

  HSI3.2 camera failed. HSI2.1 camera transferred to HSI3.2

• Flight 1: July 3	no HSI2.1	Western Lake Erie
• Flight 2: July 9	no HSI2.1	
• Flight 3: Aug 2	no HSI2.1	
• Flight 4: Aug 14	no HSI2.1	
• Flight 5: Aug 23	HSI2.1 INS not working	Harsha Lake
• Flight 6: Aug 27	HSI2.1 and HSI3.2 working	Western Lake Erie
• Flight 7: Sept 14		
• Flight 8: Sept 17		
• Flight 9: Sept 28	note: HSI3 on laptop	
• Flight 10: Oct 1		
• Flight 11: Oct 12		Harsha Lake

2019 Flight Schedule and Issues

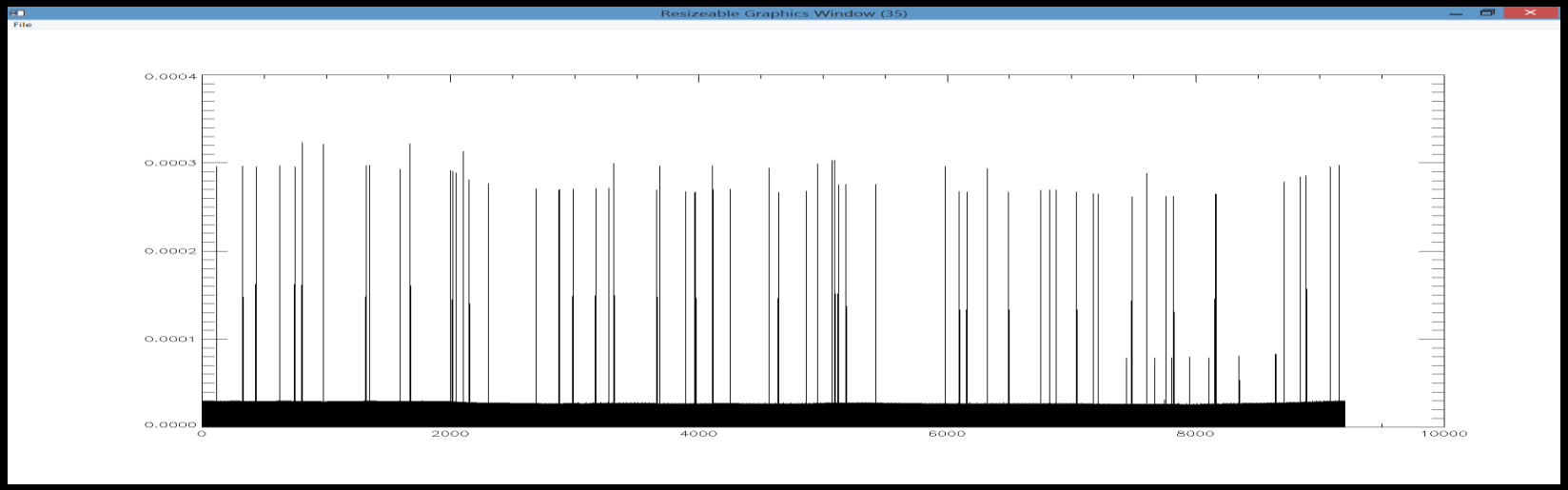
Flew HSI3.2 and new HSI Cubesat

HSI3.2: new rack servo comp swapped to CF-31 laptop

- Flight 1: Aug 9 — HSI3.2 noticed image freezing issue — Western Lake Erie
- Flight 2: Aug 16 — HSI3.2 Freezing issue
- Flight 3: Aug 21 — HSI3.2 rack computer swapped with laptop before flight. Freezing images reduced.
- Flight 4: Aug 23 — Radiometer started late in flight
- Flight 5: Aug 28
- Flight 6: Aug 30
- Flight 7: Sept 6 — Harsha Lake
- Flight 8: Sept 26 — Video Documentary — Western Lake Erie
- Flight 9: Sept 27 — Harsha Lake

Longitude noise comparison when rack computer swapped for laptop

Flight 2



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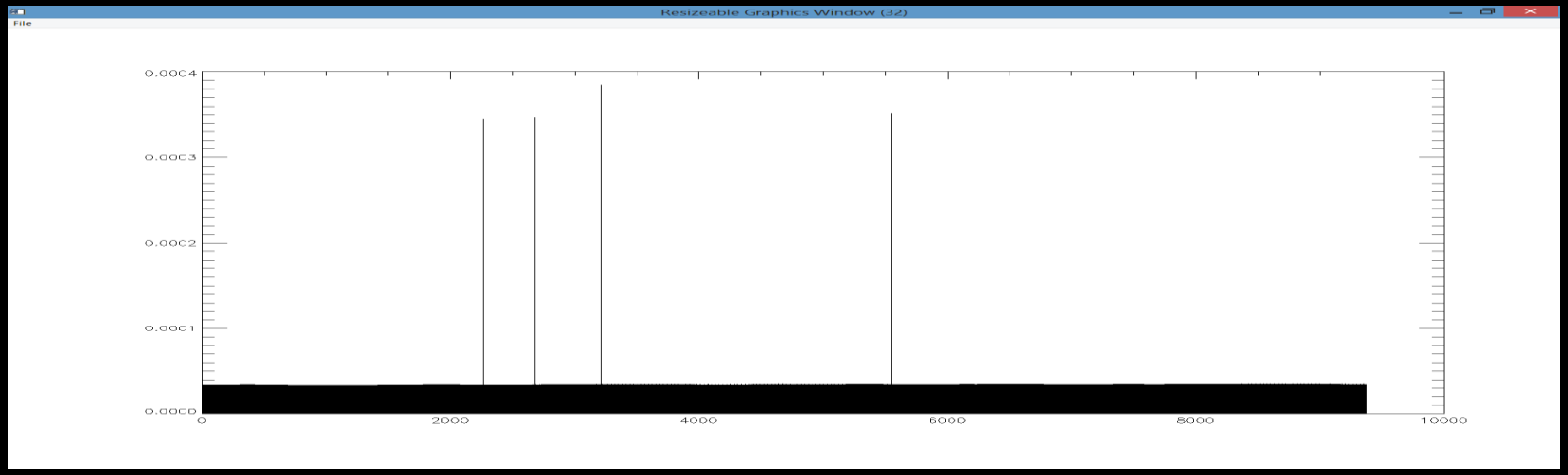
Flight 3



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Thank You

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