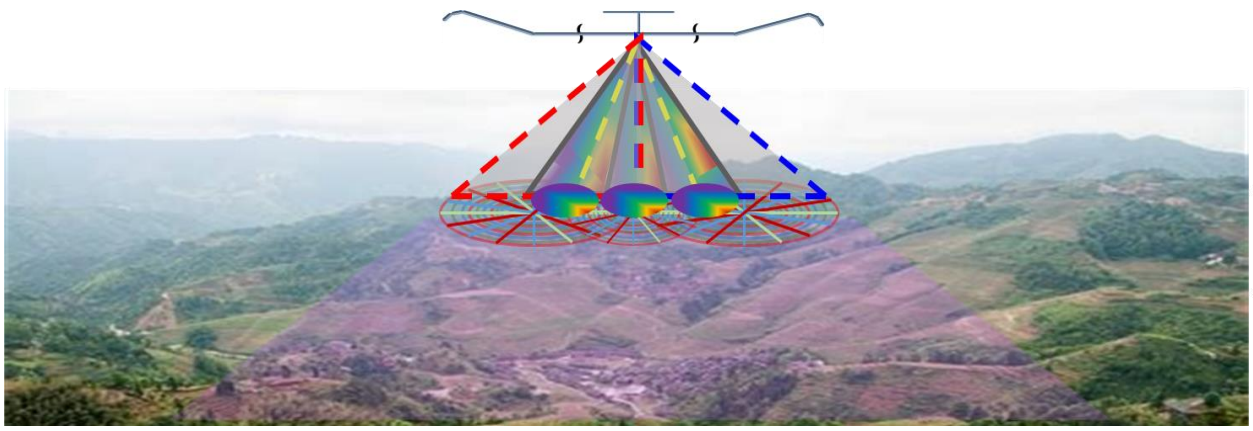
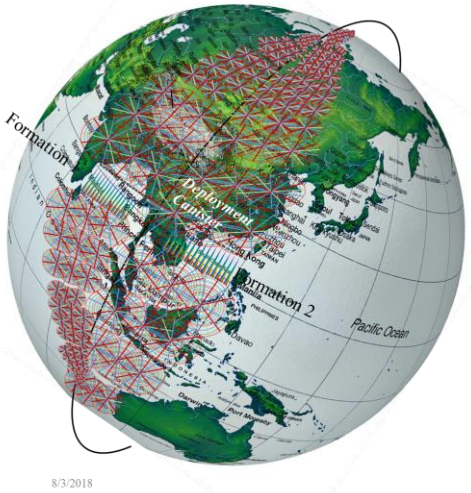
"Hyper-spectral, UHD imaging NANO-SAT formations or HAPS to detect, identify, geolocate and track; CBRN gases, fuel vapors and other substances

Arnold Kravitz

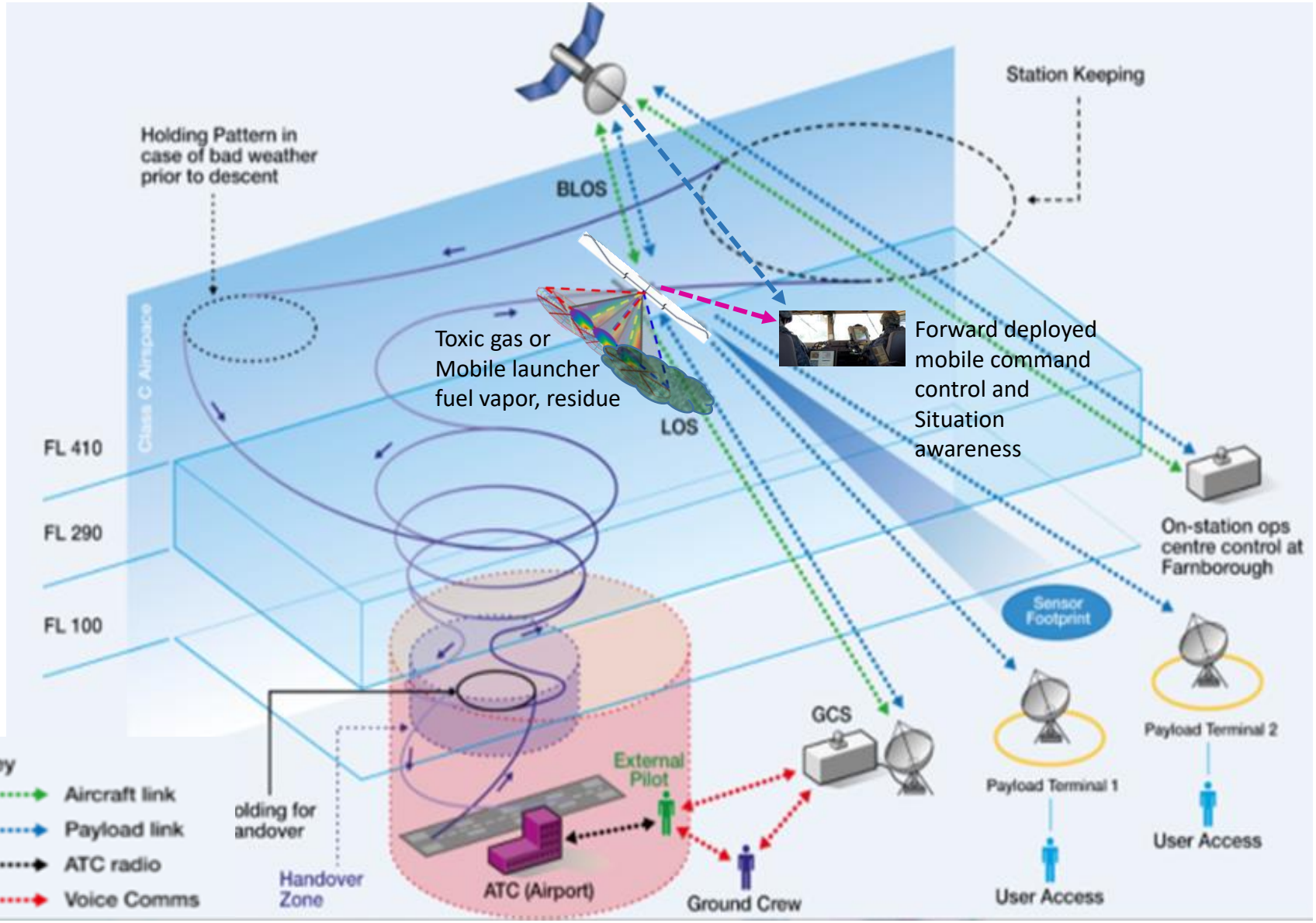




HSI and FMV Nano-sensor for UHD stereo persistent surveillance

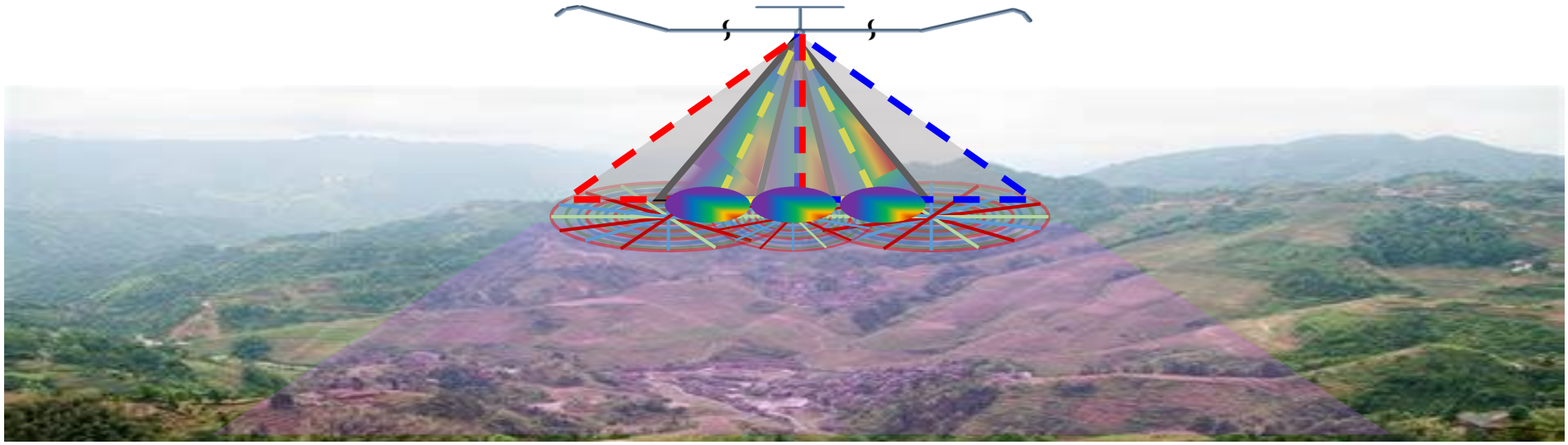
1. Detect, identify, track, and geo locate; gases vapers, and materials via hyperspectral imaging.
2. High resolution real time UHD stereo persistent surveillance co bore sighted with the Hyper spectral imager
3. Dual use as a Nanosat formation or HAPS payload

HAPS Mission Concept

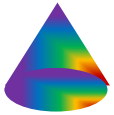


Curtesy of Airbus Defense and Space

HAPS Imaging Concept

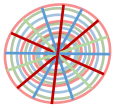


Hyper spectral ground track



1) Hyperspectral camera ground tracks, over lap each other to form stereo imagery each other,
2) Specifics
   - Altitude 21.4 km (70,000' alt)
   - FOV 6 deg.
   - Ground swath 6.7 km
   - Resolution 744 m (via sub pixel approximation)

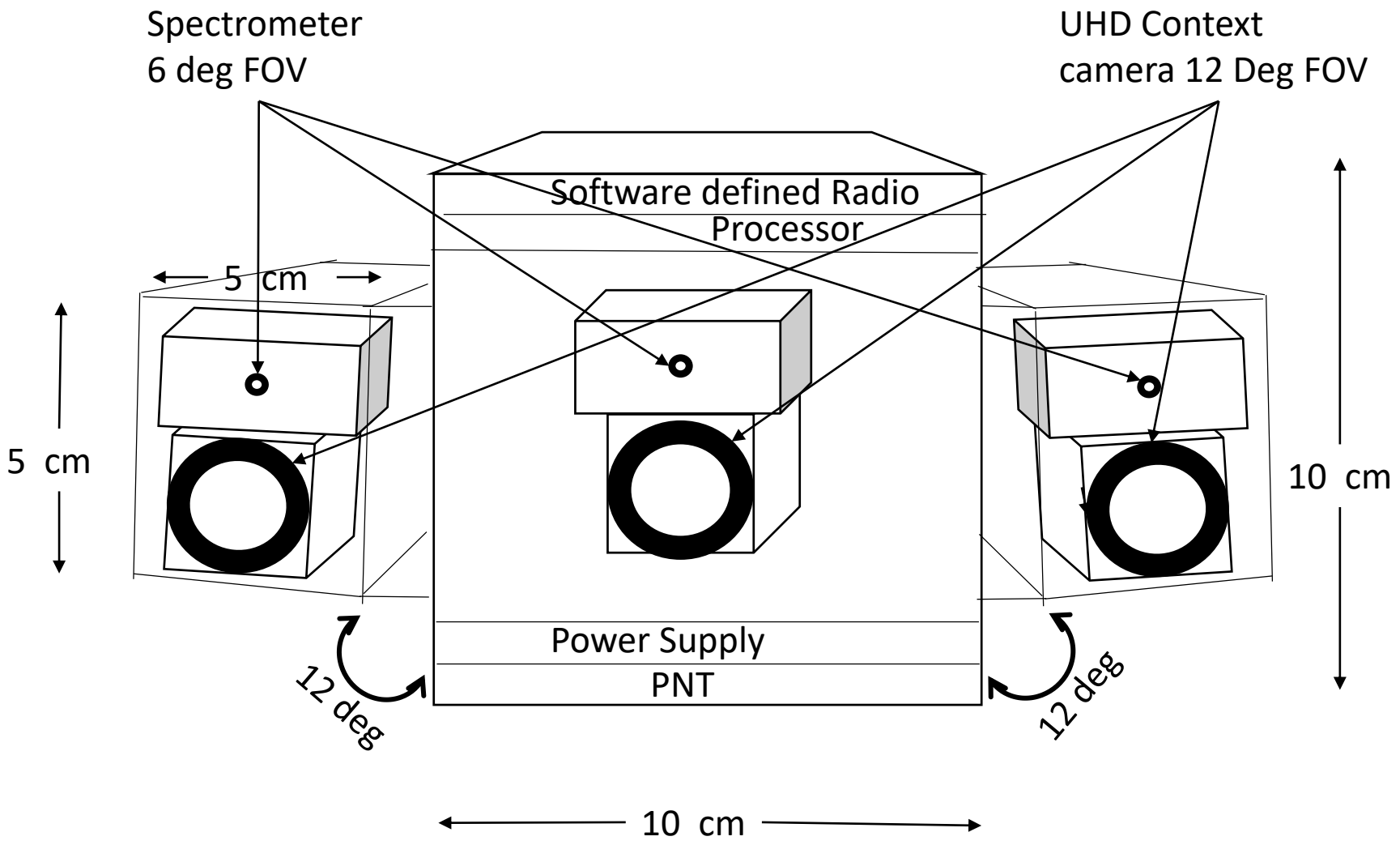
Stereoscopic Context ground track



1) Context camera ground tracks, over lap each other to form stereo imagery each other,
2) Specifics
   - Altitude 21.4 km (70,000' alt)
   - FOV 12 deg.
   - Ground Swath 8.9 km
   - Resolution 29 cm (via sub pixel approximation)
   - Stereo vision via instrument 6 deg canting and 50 % overlap

HAPS Payload Major System Components

HAPS Payload Concept



Operationally responsive HAPS mission overview

- Commodity instrument commercial components
- Extended mission (months)
- Persistent Hyperspectral stereo imagery
- Full color (RGB) still and FMV (30-120 Hz frame rate) stereoscopic
  - overlapping ground swaths
  - Full coverage
  - Live video streaming RGB
  - Live stereo video streaming
- Fused Hyperspectral/ RGB imagery
- Resolution

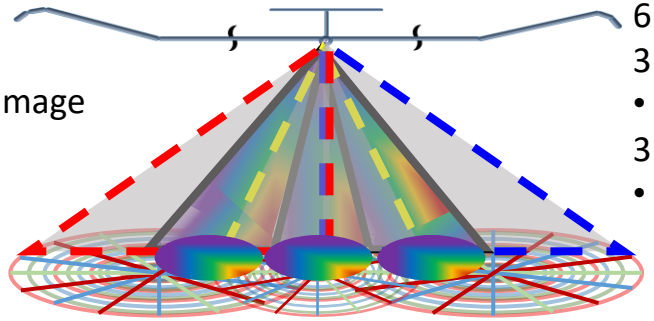
Alt.	70,000’	60,000”	30,000”
RGB	0.29 m	0.25 m	0.049 m
HSI	744 m	638 m	319 m

- Reliability thru redundancy and graceful degradation
- Hyper spectral imagery
  - 6 degree FOV
  - Frame rate up to 30 frames / second over target
  - CMOS Spectrometer readout by cell with varying TDI intervals to maximize dynamic range.
    - Frame to frame analysis
    - If saturated readout speed is accelerated
    - If level is too low integration time is increased
- X, and ka band (2-4 Ghz or 8-12 Ghz, or 28.8 Ghz down link
- Long range vision; is commercial weather/ commodity monitoring
- Goal of a dual use payload suitable as a 1 u battery powered nanosat, HAPS Payload, or a UAV payload with component subtraction.

Video frame assembly and stereo overlap

UHD Visible band Stereo

- 12 deg FOV
- 6 deg off set camera to camera
- 10% proportionality side image to top image
- 50% overlap out side cameras (6 deg)
- 100% overlap center camera



Hyper-Spectral frame

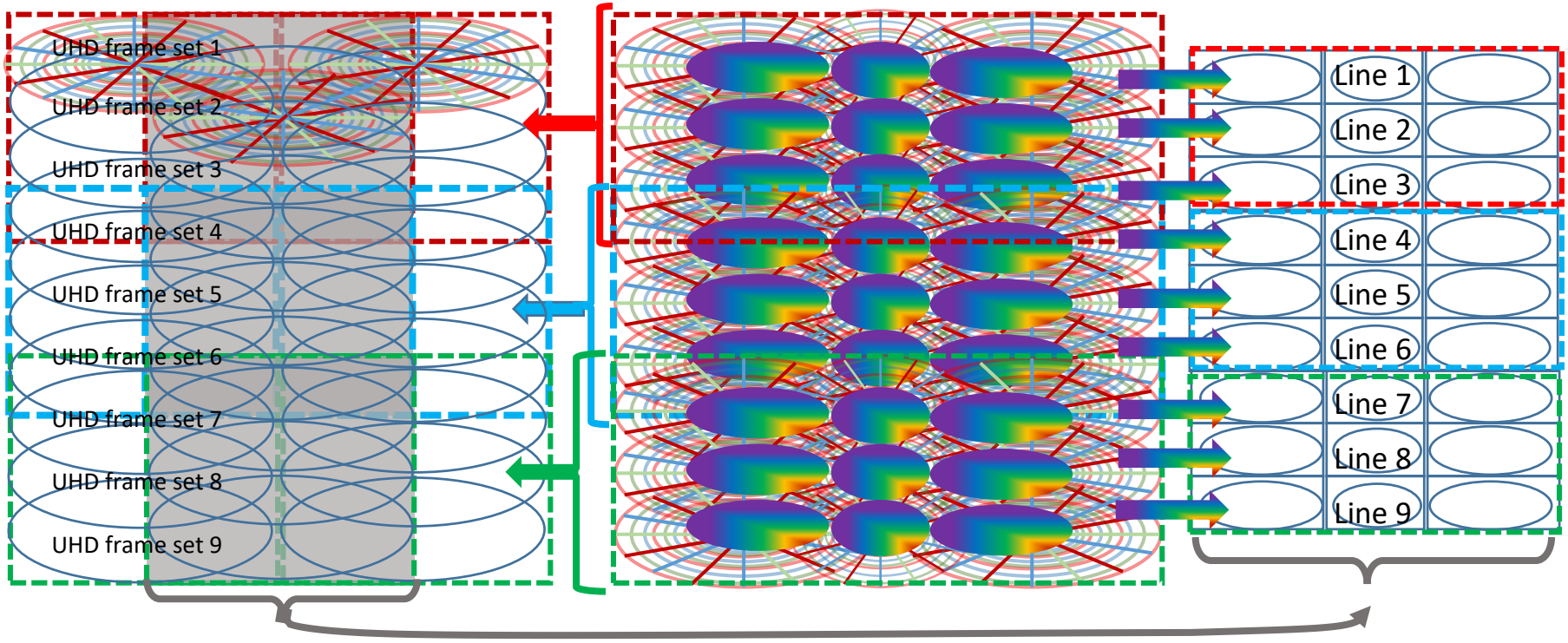
6 deg FOV

3 cameras aligned edge to edge

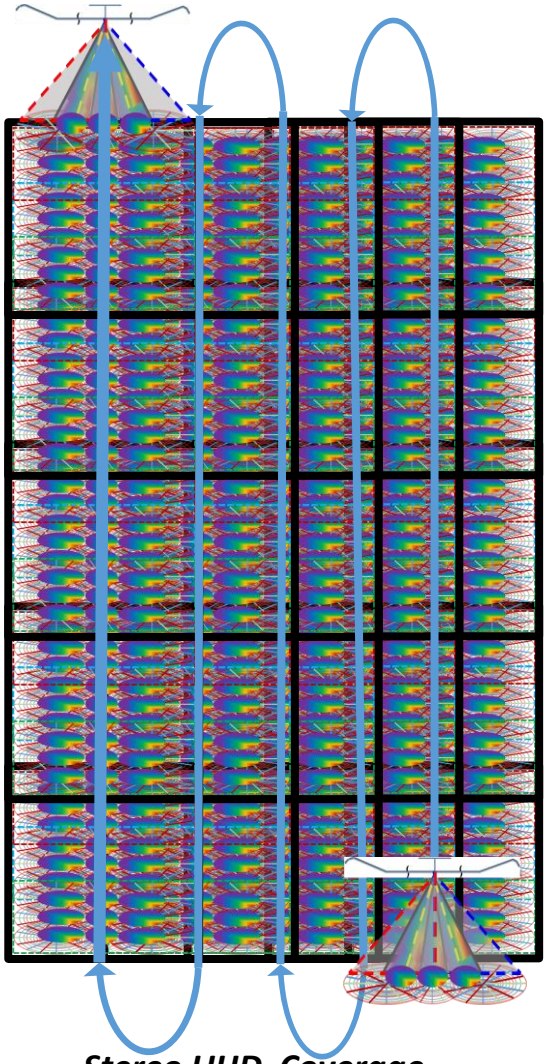
- 1x3 line array

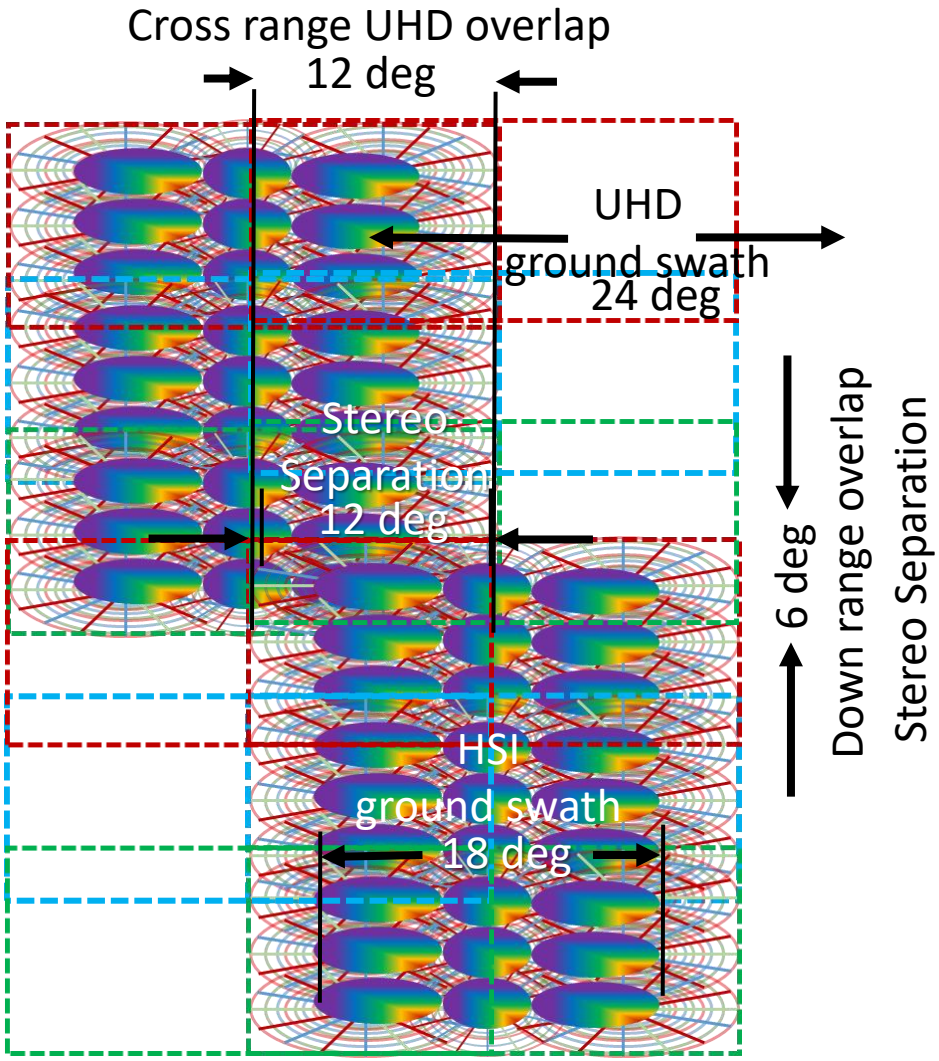
3 consecutive lines form a 3x3 array

- Full area coverage
  - Frame = 3x3 array
  - Adjacent spatial frames
  - Via Flight path



Flight path, camera pointing and 2 to 1 HSI/UHD FOV ratio enables UHD stereo and line-scan gap free HSI coverage





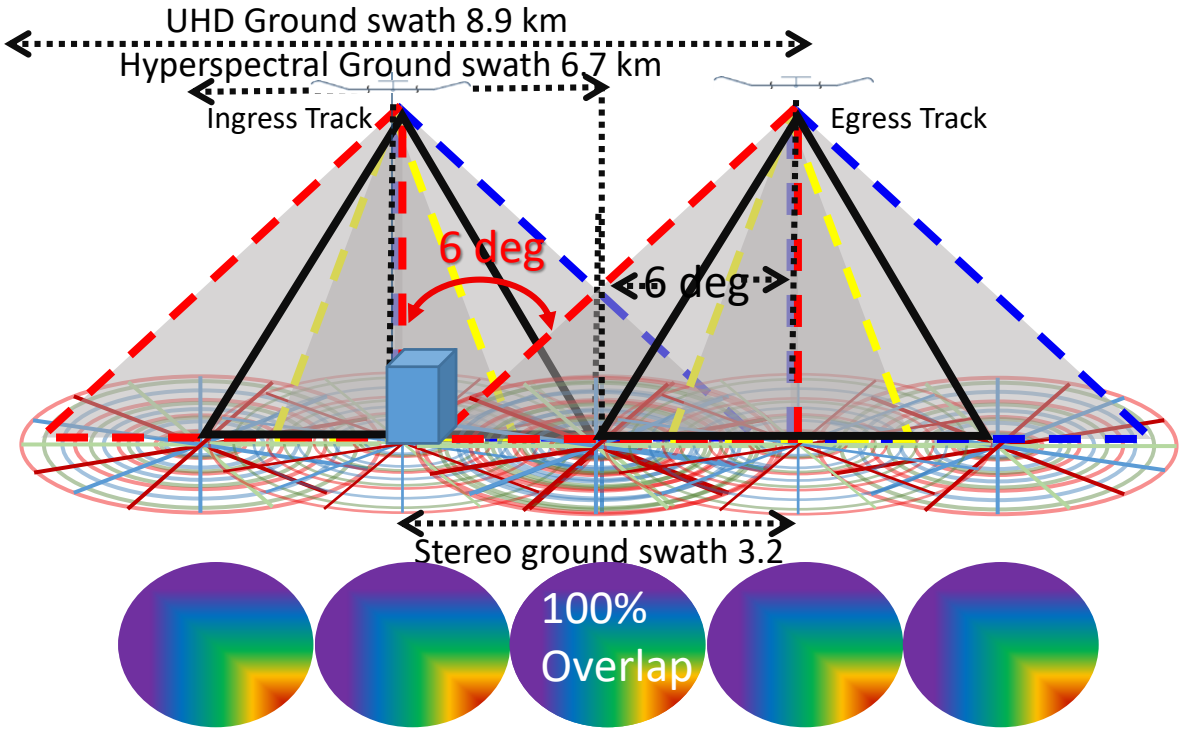
Stereo UHD Coverage

- 10.1% overlap frame to frame
- 1 outside camera image overlap via flight path

Hyperspectral imagery coverage

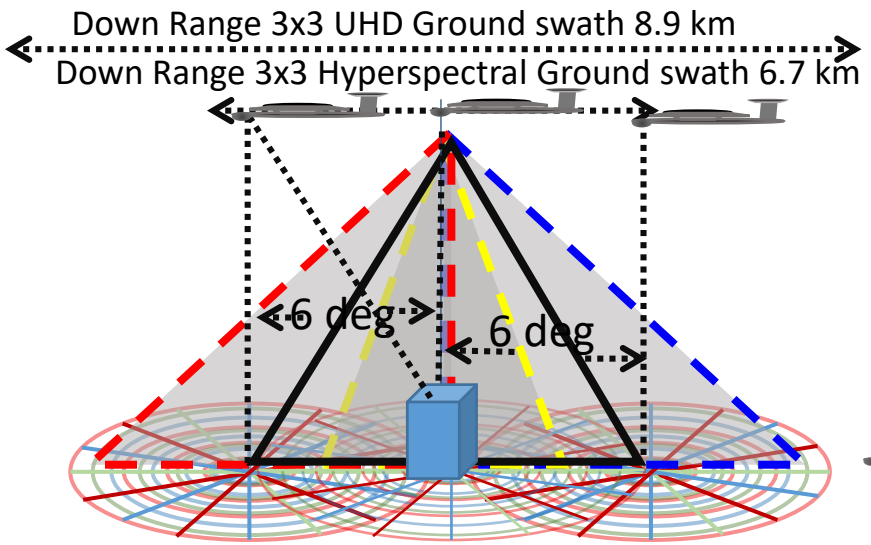
- Continuous coverage via flight path

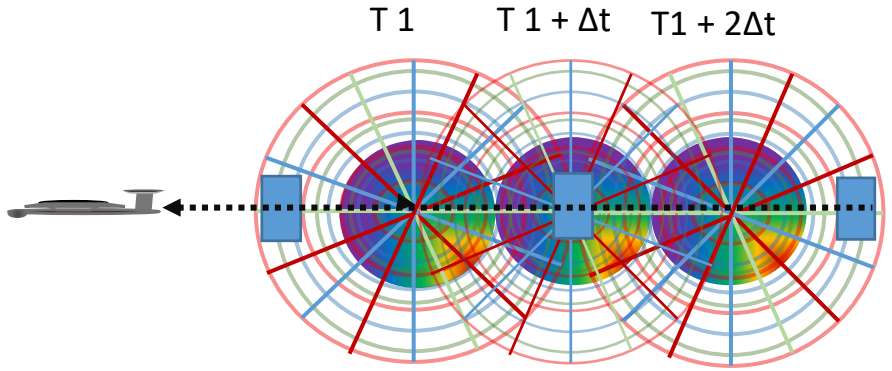
Cross range UHD 3d imagery



- Constructed from track separation angle .
- Object height perspective set by HSI overlap angle
- Object appears in different locations in multiple cameras on overlapping tracks
  a) Ingress Track 1, Center camera, location is at 0 deg
  b) Ingress Track 1, right camera, location is 6 deg left of center
  c) Egress Track 2, right camera 1 location is 6 deg right of center
- Vertical Image perspective scaling = tan(6 deg) = 10.5% true height
- Resolution = 2 x 21.3km sin(6 deg)/4072 pixels *1000/3 = 0.29 m (11 inches)

Down range UHD 3d imagery





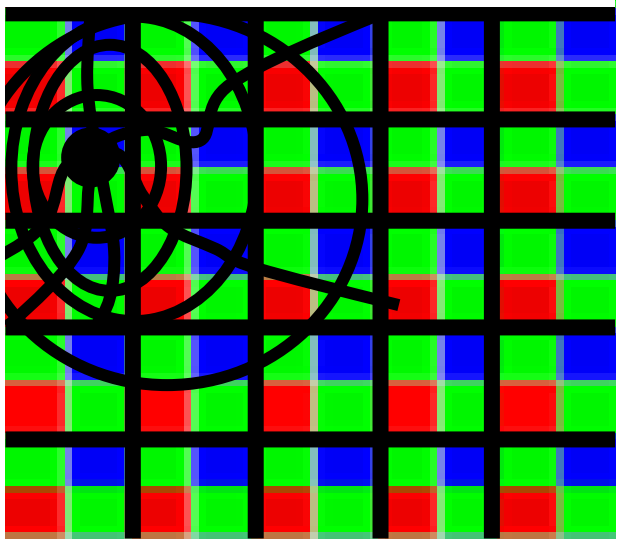
- Constructed from down range separation.
- Image Object height perspective scaling is via location geometry
- Object appears in different locations in different frames
  a) Frame 1 location is 6 deg above the top of frame
  b) Frame 2 location is center of frame
  c) Frame 3 location is 6 deg below center
  d) Vertical perspective scale = tan(6 deg) = 10.5% height
- Resolution = 2 x 21.3km sin(6 deg)/4072 pixels *1000/3
- = 0.29 m (11 inches)

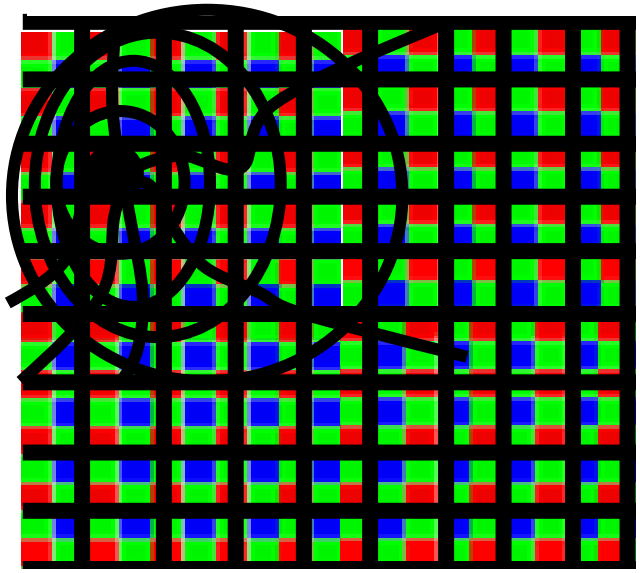
Important: The Hyperspectral frame rate for continuous coverage allows UHD Stereo Video creation same object will appear 3 times with 6 deg of separation including a top down view

HAPS Imaging Parameters

	Pixels h								4072.000	4072.000
	pixels V								3046.000	3046.000
	pixels d					1			5085.204	5085.204
	FOV(deg)					6	12			
	FOV(rad)					0.10473	0.20946			
	dif limit @F1(m)					0.000488	0.000488			
wing span (m)	alt (ft)	alt(km)	sensor spacing (m)	Single sensor Hyper spectral ground swath	3 sensor Hyper spectral ground swath (edge to edge)	Sub Pixel aprox. Hyper spectral Ground res. (m)	UHD Color Ground swath (m)	3 sensor UHD ground swath (50% sensor over lap)	Sub Pixel aprox. Ground res. METERS	Sub Pixel aprox. Ground res. INCHES
0	70000	21.336	11.25	2234.52	6703.56	744.84	4469.04	8938.08	0.29	11.533
	67500	20.574	11.25	2154.72	6464.15	718.24	4309.43	8618.86	0.28	11.12
	65000	19.812	11.25	2074.91	6224.73	691.64	4149.82	8299.64	0.27	10.71
	62500	19.05	11.25	1995.11	5985.32	665.04	3990.21	7980.43	0.26	10.30
	60000	18.288	11.25	1915.30	5745.91	638.43	3830.60	7661.21	0.25	9.89
	57500	17.526	11.25	1835.50	5506.49	611.83	3671.00	7341.99	0.24	9.47
	55000	16.764	11.25	1755.69	5267.08	585.23	3511.39	7022.77	0.23	9.06
	52500	16.002	11.25	1675.89	5027.67	558.63	3351.78	6703.56	0.22	8.65
	50000	15.24	11.25	1596.09	4788.26	532.03	3192.17	6384.34	0.21	8.24
	47500	14.478	11.25	1516.28	4548.84	505.43	3032.56	6065.12	0.20	7.83
	45000	13.716	11.25	1436.48	4309.43	478.83	2872.95	5745.91	0.19	7.41
	42500	12.954	11.25	1356.67	4070.02	452.22	2713.34	5426.69	0.18	7.00
	40000	12.192	11.25	1276.87	3830.60	425.62	2553.74	5107.47	0.17	6.59
	37500	11.43	11.25	1197.06	3591.19	399.02	2394.13	4788.26	0.16	6.18
	35000	10.668	11.25	1117.26	3351.78	372.42	2234.52	4469.04	0.15	5.77
	32500	9.906	11.25	1037.46	3112.37	345.82	2074.91	4149.82	0.14	5.35
	30000	9.144	11.25	957.65	2872.95	319.22	1915.30	3830.60	0.13	4.94
	27500	8.382	11.25	877.85	2633.54	292.62	1755.69	3511.39	0.12	4.53
	25000	7.62	11.25	798.04	2394.13	266.01	1596.09	3192.17	0.10	4.12
	22500	6.858	11.25	718.24	2154.72	239.41	1436.48	2872.95	0.09	3.71
	20000	6.096	11.25	638.43	1915.30	212.81	1276.87	2553.74	0.08	3.30
	17500	5.334	11.25	558.63	1675.89	186.21	1117.26	2234.52	0.07	2.88
	15000	4.572	11.25	478.83	1436.48	159.61	957.65	1915.30	0.06	2.47
	12500	3.81	11.25	399.02	1197.06	133.01	798.04	1596.09	0.05	2.06
	10000	3.048	11.25	319.22	957.65	106.41	638.43	1276.87	0.04	1.65
	7500	2.286	11.25	239.41	718.24	79.80	478.83	957.65	0.03	1.24
	5000	1.524	11.25	159.61	478.83	53.20	319.22	638.43	0.02	0.82
	2500	0.762	11.25	79.80	239.41	26.60	159.61	319.22	0.01	0.41
	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sub pixel approximation used to minimize jitter ease optical requirements and improve resolution





1. The signal as read by adjacent pixels
2. The data is curve fit
   - Sets of 3 pixels in vertical, horizontal and diagonal.
3. The result is then mapped from the 3x3 to a 9x9 and
4. Values for the higher density pixels are calculated.

Pixel intensity values

(note each pixel is a spectrometer with 200+ colors Approximation is done on the ground for each frequency.)

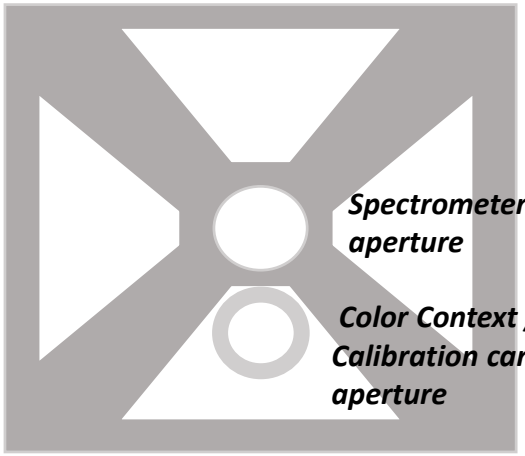
2	5	3
3	9	2
5	6	3

Pixel approximate values

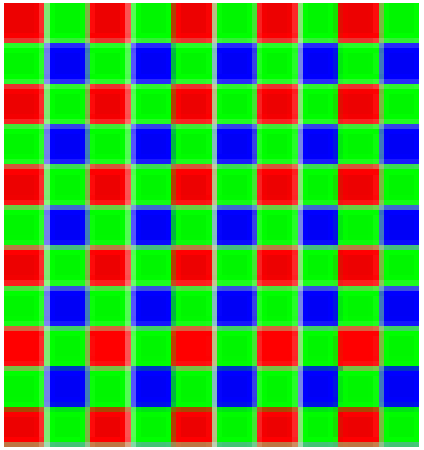
(note each pixel is a spectrometer with 200+ colors Approximation is done on the ground for each frequency.)

1	3	2	2	1				
0	4	3	2	1	1	0	0	0
1	5	4	3	2	1	0	0	0
2	9	6	3	2	1	0	0	0
2	4	5	3	2	1	0	0	0
1	2	2	3	2	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

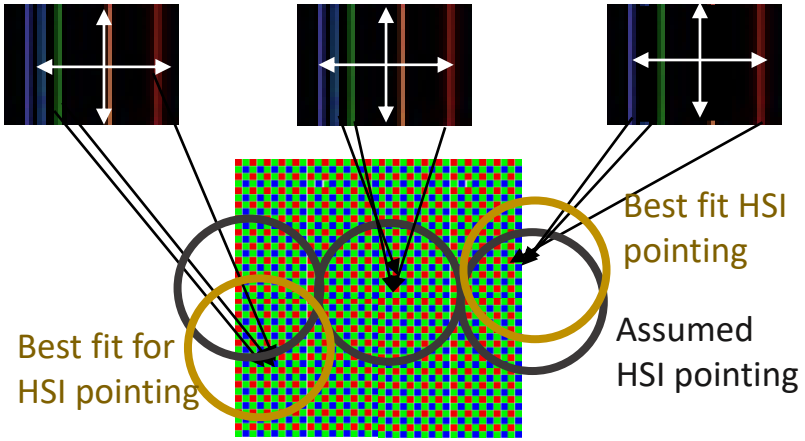
Pointing angle determination leverages the Bayer filter data to template match the HAPS instrument spectrometers to the scene to best determine the look angle and compensate for boresight misalignments, temperature variation shifting shock induced movement



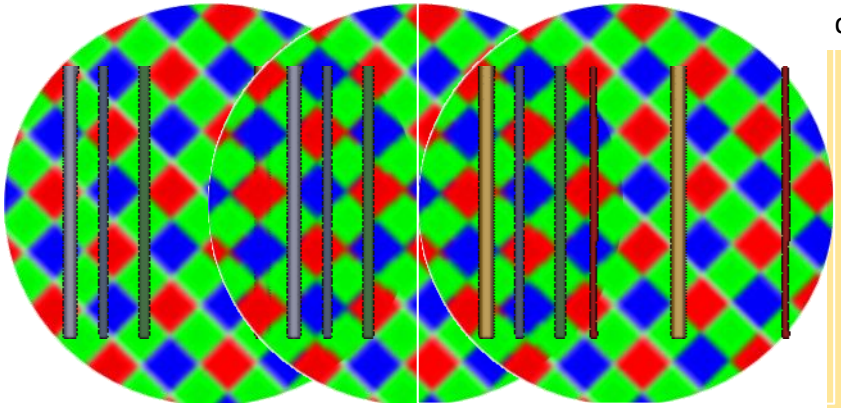
Color context camera Bayer pattern is used to provide a red green blue signature for the scene data for each geo-located ground image



The spectrometers readings are then normalized to red green and blue and the 3 sets are template matched to the nearest best fit to determine a geolocated look angle



The ground segment processing then looks at the off set and provides corrected imagery by shifting or rotating the imagery back into the desired alignment.

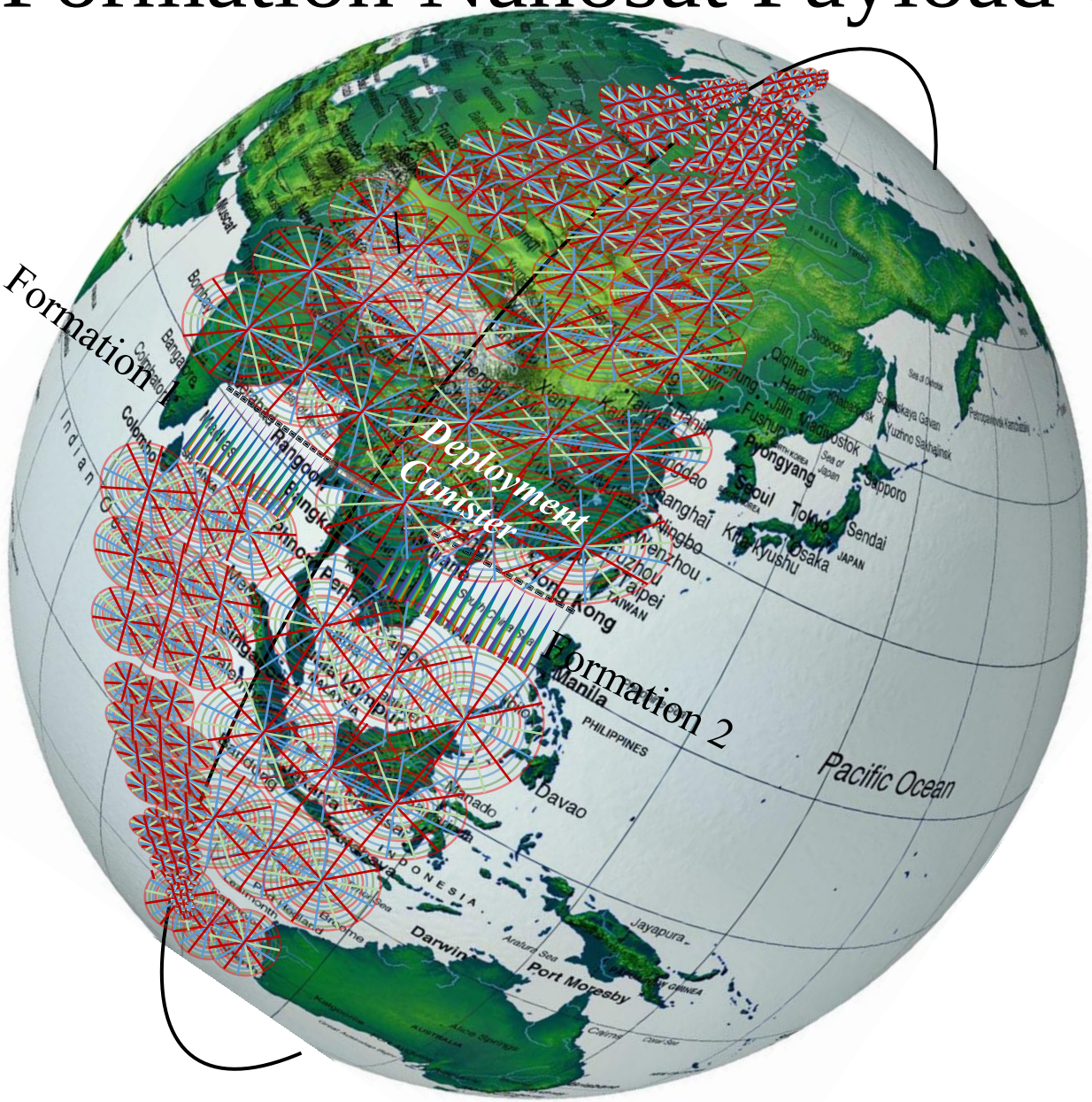


Note; all optical elements are calibrated on the ground. Pointing may be corrected via image processing on the ground or on orbit

Each instrument has a PNT measurement unit the rotation rates, (clocking angle, coning angle, and centration are used to correct and align the imagery.

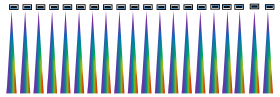
Data type	Image correction
• Clocking angle	a flat rotation of the imager
• Coning angle	trapezoidal stretching of the imagery
• Centration	Horizonal or vertical shifting of the imagery
• Planar Translation	flat scaling of the imagery

Formation Nanosat Payload Concept



Context camera ground track

Hyper spectral ground track

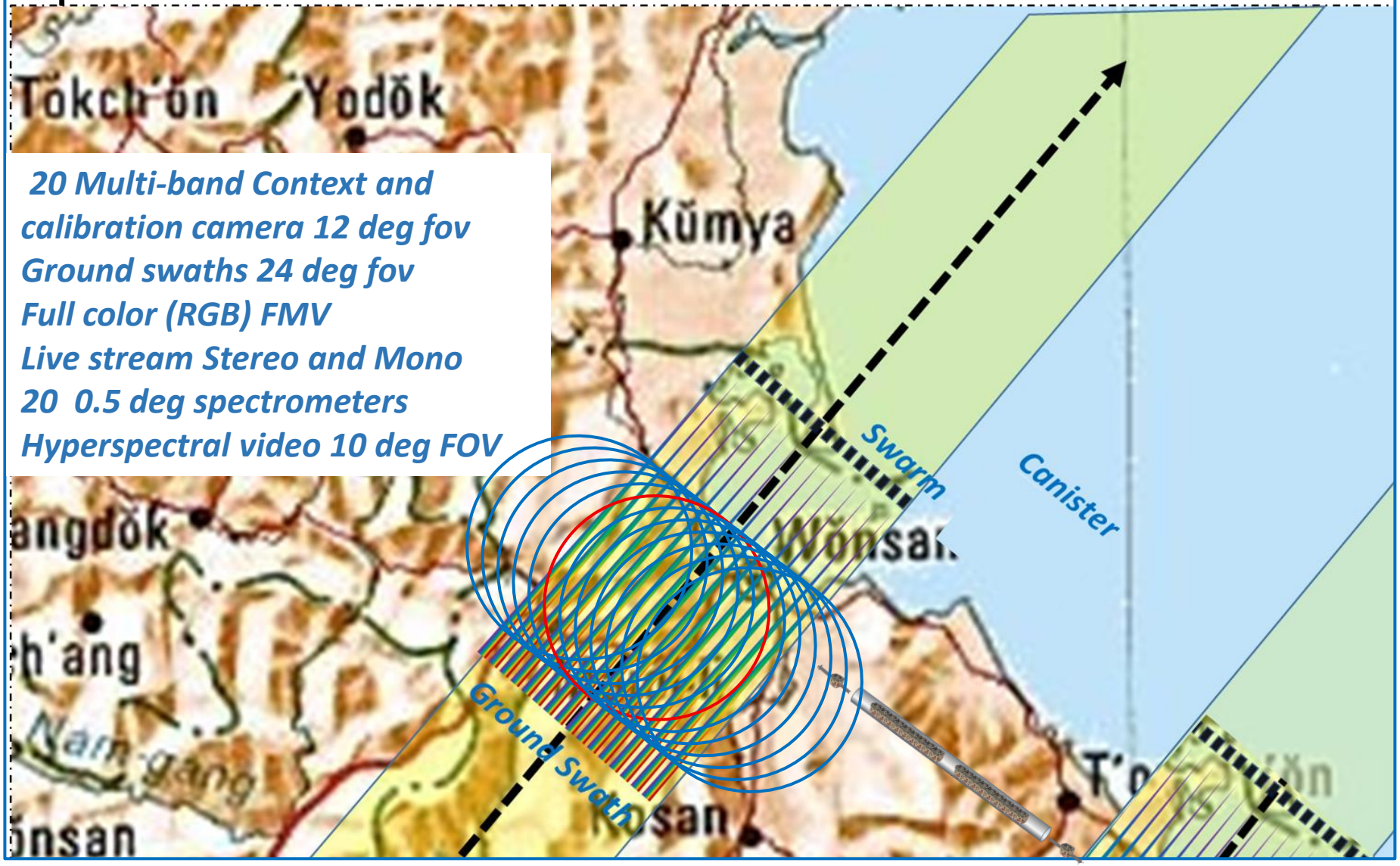


Note;

1) The context camera ground tracks, abut each other, orbit to orbit at max altitude and over lap as orbit decays.
2) Specifics

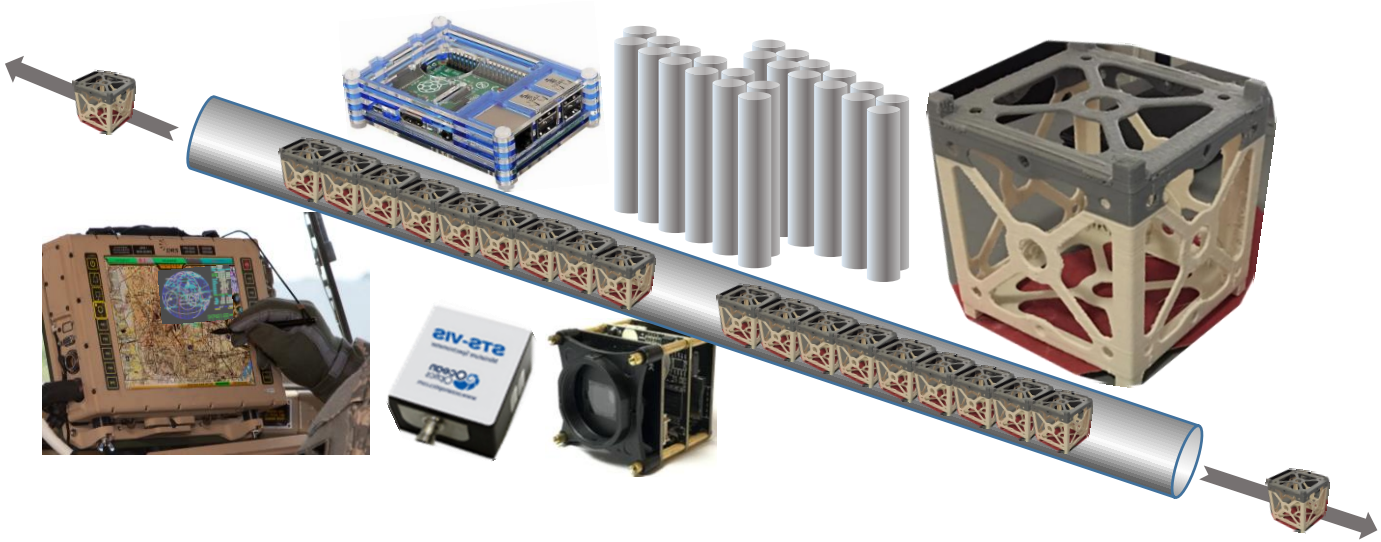
- Orbit- 274 km polar
- 16 orbits / day
- Period -1.5 hrs,
- UHD Context camera
  - FOV 12 deg.
  - Resolution 4.7 m
- Stereo vision via cube to cube spacing
  - 85.8Km ground swath
    - 20 Nanosat formation
  - 6 deg stereo separation
    - 1st to 8th and 10 nanosat
    - 28.6 km separation
  - Vertical scaling =10.5%

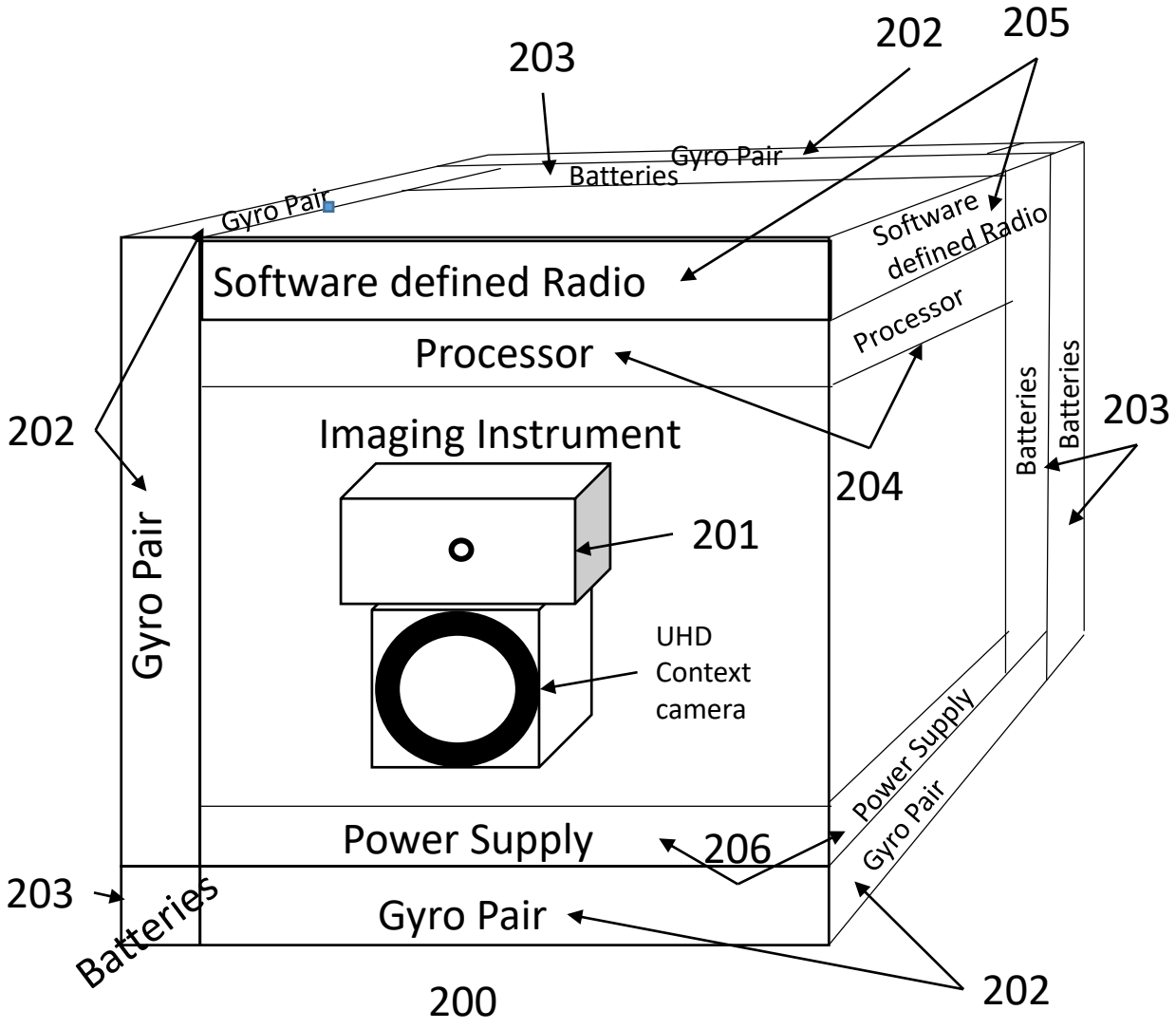
Spectrometer Swarm - Ground Swath



20 Multi-band Context and calibration camera 12 deg fov
Ground swaths 24 deg fov
Full color (RGB) FMV
Live stream Stereo and Mono
20 0.5 deg spectrometers
Hyperspectral video 10 deg FOV

Major System Components





Cube Sat

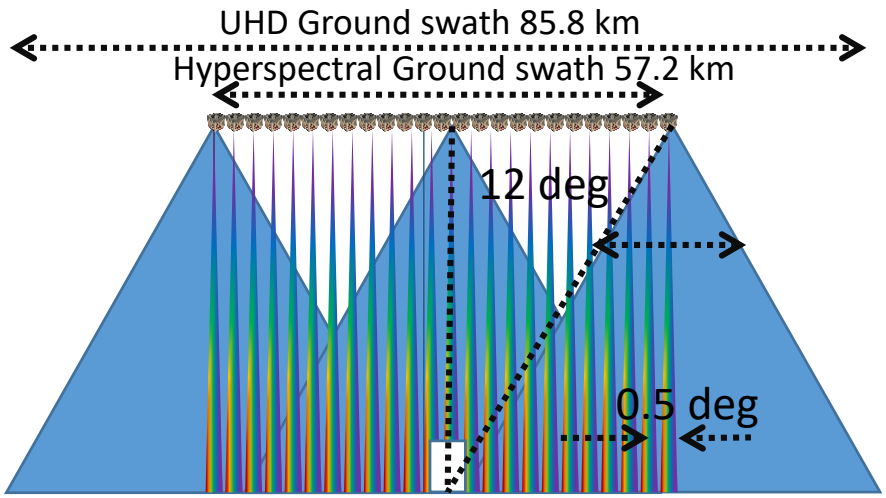
A **CubeSat** (U-class spacecraft) is a type of miniaturized satellite for space research made up of multiples of 10×10×11.35 cm cubic units, has a mass of no more than 1.33 kilograms per unit, and often see the use of commercial off-the-shelf (COTS) components for its electronics and structure

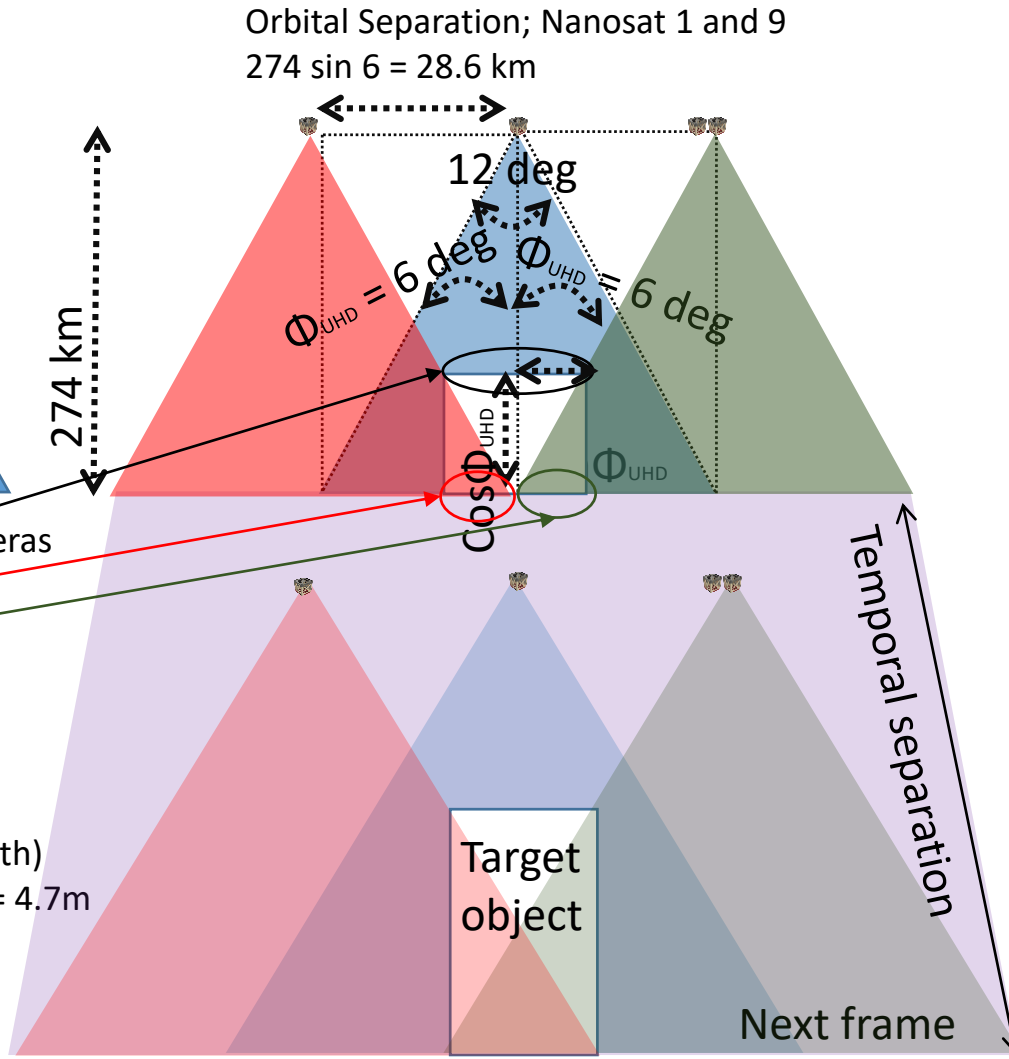
NANOSAT momentum balanced deployment

Operationally responsive Formation Nanosat

- Commodity Nano Sat (multi utility mission)
- 4 week mission
- Near earth orbit 274 Km to 80Km?
- Commercial components
- Low cost commercial launch
- Hyperspectral imagery 2/ per day
- Full color (RGB) still and FMV (30 Hz) imagery
  - 22 deg swath, 4.7m resolution
  - full gap free slightly overlapping ground swaths
  - Full coverage every 16 orbits
  - Live video streaming RGB 3d imagery
- Fused Hyperspectral/ RGB imagery
- Reliability thru redundancy and graceful degradation
- Hyper spectral imagery
  - 1/8 to ½ degree FOV for 200m to 800m resolution from 274KM
  - 10 frames over target per orbit at 30 hz
- Mono and Stereo Mono full color full motion video
  - 12 deg FOV (gap free swath to swath overlapping orbital coverage.
  - Full earth coverage every 24hrs
- X, and ka band (2-4 Ghz or 8-12 Ghz, or 28.8 Ghz down link
- Long range vision; is commercial weather/ commodity monitoring

UHD Stereo and 3d imagery is constructed from cross range separation and down range temporal displacement. 3d Scaling is determined from orbital geometry





- Object appears in different locations in multiple cameras
  a) Center camera 9, and 10,
  b) Extreme right camera 1
  c) Extreme left in camera 20
- Vertical scaling % = tan(6 deg) = 10.5%
  a) Alt,
  b) UHD-FOV,
  c) Camera separation (hyperspectral ground swath)
- Resolution = 2 x 274 sin(6 deg)/4072 pixels *1000/3 = 4.7m
- 3d imagery is constructed using the video motion to capture the down range dimension
- ***Note: Nanosats form a Single hyperspectral array preventing stereo hyperspectral imagery***

Orbital Parameters

Target revisit with a 1/8th degree FOV and 198 m (sub pixel) ground resolution at 274 km orbit

Target revisit with a 1/4th degree FOV and 396 m (sub pixel) ground resolution at 274 km orbit

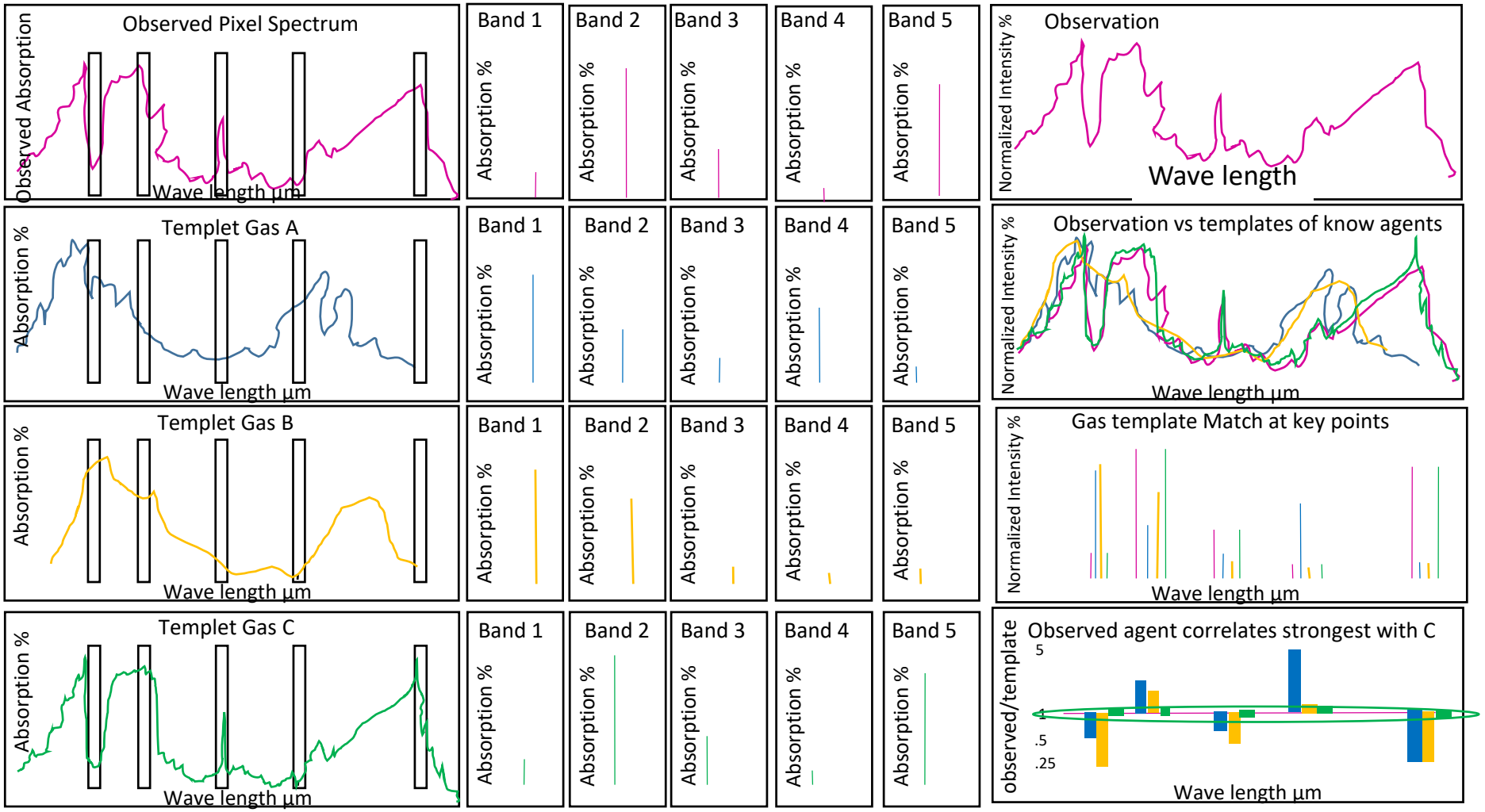
Target revisit with a 1/2th degree FOV and 791 m (sub pixel) ground resolution at 274 km orbit

Alt Km4 7.82 km and	V (Km/ sec)	T hr	T min	T Sec	Pixel Ground resolution (m) with1/3 pixel, sub pixel approximation (diameterof spot)			Gound swath width(km)			Week	0							1							2							3				
					20	20	20	20	20	20	Day	0																								
					0.125	0.25	0.5	0.125	0.25	0.5	Orbit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
								2.5	5	10		0	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320	336	352	368	384	400	416
300	7.73	1	30	31.18	0.218	0.436	0.873	13.090	26.18	52.36		0	231.40	462.80	694.20	925.60	1157.00	1388.40	1619.80	1851.20	2082.60	2314.00	2545.39	2776.79	3008.19	3239.59	3470.99	3702.39	3933.79	4165.19	4396.59	4627.99	4859.39	5090.79	5322.19	5553.59	5784.99	6016.39
298	7.73	1	30	28.74	0.217	0.433	0.867	13.003	26.01	52.01		0	213.29	426.59	639.88	853.18	1066.47	1279.76	1493.06	1706.35	1919.65	2132.94	2346.24	2559.53	2772.82	2986.12	3199.41	3412.71	3626.00	3839.29	4052.59	4265.88	4479.18	4692.47	4905.77	5119.06	5332.35	5545.65
296	7.73	1	30	26.30	0.215	0.431	0.861	12.915	25.83	51.66		0	195.19	390.38	585.57	780.77	975.96	1171.15	1366.34	1561.53	1756.72	1951.92	2147.11	2342.30	2537.49	2732.68	2927.87	3123.06	3318.26	3513.45	3708.64	3903.83	4099.02	4294.21	4489.40	4684.60	4879.79	5074.98
294	7.73	1	30	23.86	0.214	0.428	0.855	12.828	25.66	51.31		0	177.09	354.18	531.27	708.37	885.46	1062.55	1239.64	1416.73	1593.82	1770.92	1948.01	2125.10	2302.19	2479.28	2656.37	2833.47	3010.56	3187.65	3364.74	3541.83	3718.92	3896.01	4073.11	4250.20	4427.29	4604.38
292	7.73	1	30	21	0.212	0.425	0.849	12.741	25.48	50.96		0	158.99	317.99	476.98	635.98	794.97	953.97	1112.96	1271.95	1430.95	1589.94	1748.94	1907.93	2066.93	2225.92	2384.92	2543.91	2702.90	2861.90	3020.89	3179.89	3338.88	3497.88	3656.87	3815.86	3974.86	4133.85
290	7.73	1	30	19	0.211	0.422	0.844	12.654	25.31	50.61		0	140.90	281.80	422.70	563.60	704.50	845.40	986.30	1127.20	1268.10	1409.00	1549.90	1690.80	1831.70	1972.60	2113.50	2254.40	2395.30	2536.20	2677.10	2818.00	2958.90	3099.80	3240.70	3381.60	3522.50	3663.40
288	7.73	1	30	16.55	0.209	0.419	0.838	12.566	25.13	50.27		0	122.81	245.62	368.42	491.23	614.04	736.85	859.66	982.46	1105.27	1228.08	1350.89	1473.70	1596.50	1719.31	1842.12	1964.93	2087.74	2210.54	2333.35	2456.16	2578.97	2701.78	2824.58	2947.39	3070.20	3193.01
286	7.73	1	30	14.11	0.208	0.416	0.832	12.479	24.96	49.92		0	104.72	209.44	314.16	418.88	523.59	628.31	733.03	837.75	942.47	1047.19	1151.91	1256.63	1361.35	1466.07	1570.78	1675.50	1780.22	1884.94	1989.66	2094.38	2199.10	2303.82	2408.54	2513.25	2617.97	2722.69
284	7.74	1	30	11.67	0.207	0.413	0.826	12.392	24.78	49.57		0	86.63	173.27	259.90	346.53	433.16	519.80	606.43	693.06	779.69	866.33	952.96	1039.59	1126.22	1212.86	1299.49	1386.12	1472.75	1559.39	1646.02	1732.65	1819.28	1905.92	1992.55	2079.18	2165.81	2252.45
282	7.74	1	30	9.24	0.205	0.410	0.820	12.305	24.61	49.22		0	68.55	137.10	205.65	274.20	342.74	411.29	479.84	548.39	616.94	685.49	754.04	822.59	891.14	959.68	1028.23	1096.78	1165.33	1233.88	1302.43	1370.98	1439.53	1508.08	1576.63	1645.17	1713.72	1782.27
280	7.74	1	30	6.80	0.204	0.407	0.814	12.217	24.43	48.87		0	50.47	100.94	151.40	201.87	252.34	302.81	353.28	403.74	454.21	504.68	555.15	605.62	656.08	706.55	757.02	807.49	857.96	908.42	958.89	1009.36	1059.83	1110.30	1160.76	1211.23	1261.70	1312.17
278	7.74	1	30	4.36	0.202	0.404	0.809	12.130	24.26	48.52		0	32.39	64.78	97.17	129.56	161.95	194.34	226.73	259.12	291.51	323.90	356.29	388.68	421.07	453.46	485.85	518.24	550.63	583.02	615.41	647.80	680.18	712.57	744.96	777.35	809.74	842.13
276	7.74	1	30	1.93	0.201	0.401	0.803	12.043	24.09	48.17		0	14.31	28.63	42.94	57.26	71.57	85.89	100.20	114.51	128.83	143.14	157.46	171.77	186.09	200.40	214.71	229.03	243.34	257.66	271.97	286.28	300.60	314.91	329.23	343.54	357.86	372.17
274	7.74	1	29	59.49	0.199	0.399	0.797	11.956	23.91	47.82		0	40071.24	40067.48	40063.72	40059.97	40056.21	40052.45	40048.69	40044.93	40041.17	40037.41	40033.66	40029.90	40026.14	40022.38	40018.62	40014.86	40011.10	40007.35	40003.59	39999.83	39996.07	39992.31	39988.55	39984.79	39981.04	39977.28
272	7.74	1	29	57.06	0.198	0.396	0.791	11.868	23.74	47.47		0	40053.17	40031.34	40009.51	39987.69	39965.86	39944.03	39922.20	39900.37	39878.54	39856.71	39834.89	39813.06	39791.23	39769.40	39747.57	39725.74	39703.91	39682.08	39660.26	39638.43	39616.60	39594.77	39572.94	39551.11	39529.28	39507.46
270	7.74	1	29	54.62	0.196	0.393	0.785	11.781	23.56	47.12		0	40035.10	39995.21	39955.31	39915.42	39875.52	39835.62	39795.73	39755.83	39715.94	39676.04	39636.14	39596.25	39556.35	39516.46	39476.56	39436.66	39396.77	39356.87	39316.98	39277.08	39237.18	39197.29	39157.39	39117.50	39077.60	39037.70
268	7.74	1	29	52.19	0.195	0.390	0.780	11.694	23.39	46.77		0	40017.04	39959.08	39901.12	39843.16	39785.20	39727.24	39669.28	39611.31	39553.35	39495.39	39437.43	39379.47	39321.51	39263.55	39205.59	39147.63	39089.67	39031.71	38973.75	38915.79	38857.83	38799.87	38741.91	38683.94	38625.98	38568.02
266	7.75	1	29	49.76	0.193	0.387	0.774	11.606	23.21	46.43		0	39998.98	39922.95	39846.93	39770.91	39694.89	39618.86	39542.84	39466.82	39390.80	39314.77	39238.75	39162.73	39086.71	39010.68	38934.66	38858.64	38782.62	38706.59	38630.57	38554.55	38478.53	38402.50	38326.48	38250.46	38174.44	38098.41
264	7.75	1	29	47.32	0.192	0.384	0.768	11.519	23.04	46.08		0	39980.92	39886.84	39792.75	39698.67	39604.59	39510.51	39416.43	39322.35	39228.26	39134.18	39040.10	38946.02	38851.94	38757.86	38663.77	38569.69	38475.61	38381.53	38287.45	38193.36	38099.28	38005.20	37911.12	37817.04	37722.96	37628.87
262	7.75	1	29	44.89	0.191	0.381	0.762	11.432	22.86	45.73		0	39962.86	39850.72	39738.59	39626.45	39514.31	39402.17	39290.03	39177.89	39065.76	38953.62	38841.48	38729.34	38617.20	38505.06	38392.93	38280.79	38168.65	38056.51	37944.37	37832.23	37720.10	37607.96	37495.82	37383.68	37271.54	37159.41
260	7.75	1	29	42.46	0.189	0.378	0.756	11.345	22.69	45.38		0	39944.81	39814.62	39684.42	39554.23	39424.04	39293.85	39163.66	39033.46	38903.27	38773.08	38642.89	38512.70	38382.50	38252.31	38122.12	37991.93	37861.74	37731.54	37601.35	37471.16	37340.97	37210.78	37080.58	36950.39	36820.20	36690.01
258	7.75	1	29	40.02	0.188	0.375	0.750	11.257	22.51	45.03		0	39926.76	39778.51	39630.27	39482.03	39333.78	39185.54	39037.30	38889.06	38740.81	38592.57	38444.33	38296.08	38147.84	37999.60	37851.35	37703.11	37554.87	37406.62	37258.38	37110.14	36961.90	36813.65	36665.41	36517.17	36368.92	36220.68
256	7.75	1	29	37.59	0.186	0.372	0.745	11.170	22.34	44.68		0	39908.71	39742.42	39576.13	39409.83	39243.54	39077.25	38910.96	38744.67	38578.38	38412.09	38245.79	38079.50	37913.21	37746.92	37580.63	37414.34	37248.05	37081.75	36915.46	36749.17	36582.88	36416.59	36250.30	36084.01	35917.71	35751.42
254	7.75	1	29	35.16	0.185	0.369	0.739	11.083	22.17	44.33		0	39890.66	39706.33	39521.99	39337.65	39153.31	38968.98	38784.64	38600.30	38415.97	38231.63	38047.29	37862.96	37678.62	37494.28	37309.94	37125.61	36941.27	36756.93	36572.60	36388.26	36203.92	36019.59	35835.25	35650.91	35466.57	35282.24
252	7.75	1	29	32.73	0.183	0.367	0.733	10.996	21.99	43.98		0	39872.62	39670.24	39467.86	39265.48	39063.10	38860.72	38658.34	38455.96	38253.58	38051.20	37848.82	37646.44	37444.06	37241.68	37039.30	36836.92	36634.54	36432.16	36229.78	36027.40	35825.02	35622.64	35420.26	35217.88	35015.50	34813.12
250	7.75	1	29	30.30	0.182	0.364	0.727	10.908	21.82	43.63		0	39854.58	39634.16	39413.74	39193.32	38972.90	38752.48	38532.06	38311.64	38091.22	37870.80	37650.38	37429.96	37209.54	36989.12	36768.70	36548.28	36327.86	36107.44	35887.02	35666.60	35446.18	35225.76	35005.34	34784.92	34564.50	34344.08
248	7.76	1	29	27.87	0.180	0.361	0.721	10.821	21.64	43.28		0	39836.54	39598.08	39359.63	39121.17	38882.71	38644.25	38405.80	38167.34	37928.88	37690.42	37451.97	37213.51	36975.05	36736.59	36498.14	36259.68	36021.22	35782.76	35544.31	35305.85	35067.39	34828.93	34590.48	34352.02	34113.56	33875.10
246	7.76	1	29	25.44	0.179	0.358	0.716	10.734	21.47	42.94		0	39818.51	39562.02	39305.52	39049.03	38792.54	38536.05	38279.55	38023.06	37766.57	37510.08	37253.59	36997.09	36740.60	36484.11	36227.62	35971.12	35714.63	35458.14	35201.65	34945.16	34688.66	34432.17	34175.68	33919.19	33662.69	33406.20
244	7.76	1	29	23.01	0.177	0.355	0.710	10.647	21.29	42.59		0	39800.48	39525.95	39251.43	38976.90	38702.38	38427.85	38153.33	37878.81	37604.28	37329.76	37055.23	36780.71	36506.18	36231.66	35957.14	35682.61	35408.09	35133.56	34859.04	34584.52	34309.99	34035.47	33760.94	33486.42	33211.89	32937.37
242	7.76	1	29	20.58	0.176	0.352	0.704	10.559	21.12	42.24		0	39782.45	39489.89	39197.34	38904.79	38612.23	38319.68	38027.13	37734.57	37442.02	37149.46	36856.91	36564.36	36271.80	35979.25	35686.70	35394.14	35101.59	34809.04	34516.48	34223.93	33931.38	33638.82	33346.27	33053.72	32761.16	32468.61
240	7.76	1	29	18.15	0.175	0.349	0.698	10.472	20.94	41.89		0	39764.42	39453.84	39143.26	38832.68	38522.10	38211.52	37900.94	37590.36	37279.78	36969.20	36658.62	36348.04	36037.46	35726.88	35416.30	35105.72	34795.14	34484.56	34173.98	33863.40	33552.82	33242.24	32931.66	32621.08	32310.50	31999.92

274 Km orbit
1:29:57 sec period (16 orbit/24hr day)
Hyper spectral pixel ground spot 2.37 KM @ ½ FOV deg
Spectrometer resolution 791m (1/3 pixel resolution via processing)
Hyperspectral Time over target 2.37km/7.47Km/sec =.32 sec
Frame rate =30 hz
frames on target 30/sec x 0.32 sec= 10

UHD
Two 20 pixel formations per canister
UHD ground swath at 12 Deg per camera (4.7m resolution)
Formation ground swath width 10 X 2.37+ 12 x Π/180 x 274= 47.6 km
Canister scan width (2 formations) = 85.2 km + separation

Template matching across multiple bands is used to identify observed gases



Sequential Algorithms

Observe

1) Either

Then

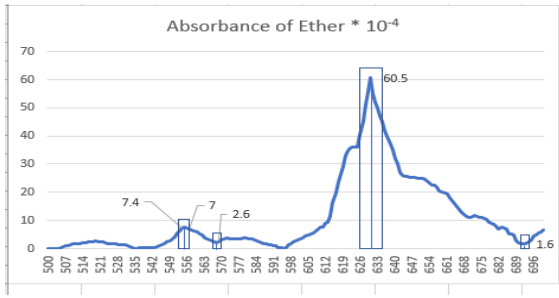
2) Ethanol

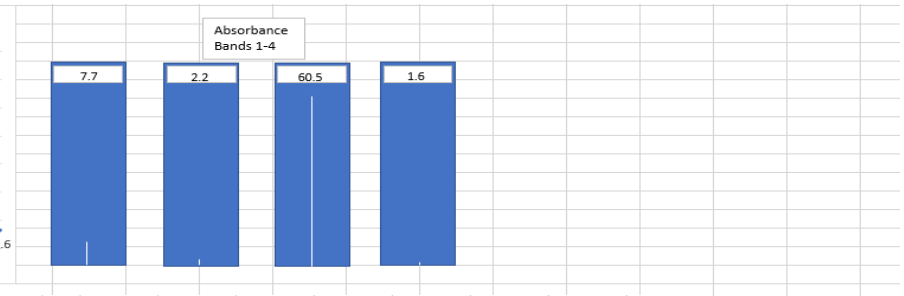
Then

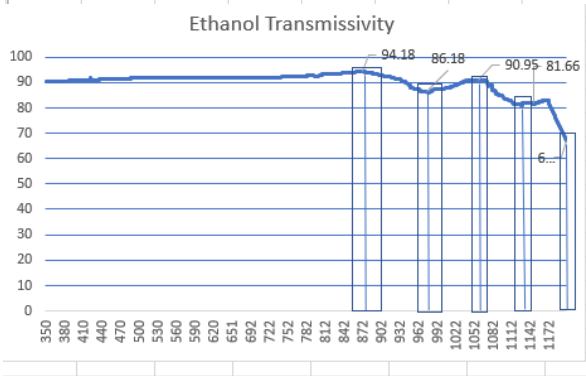
3) NCO2

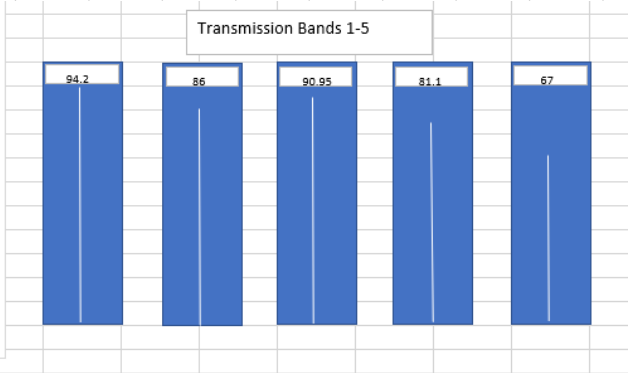
4)Petin

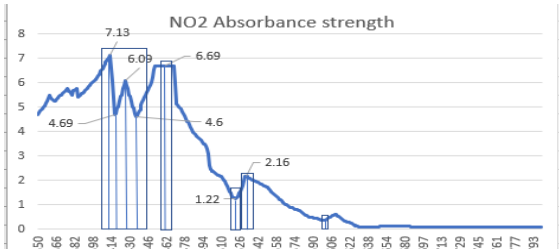
Approach with caution

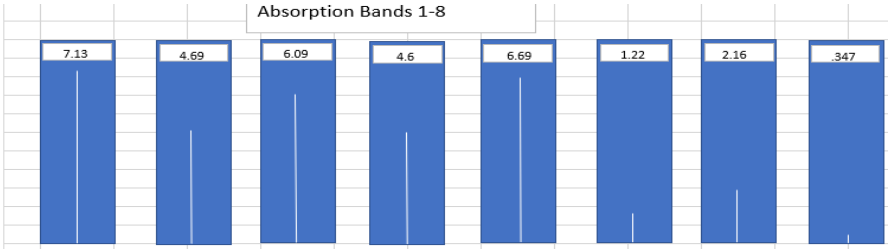


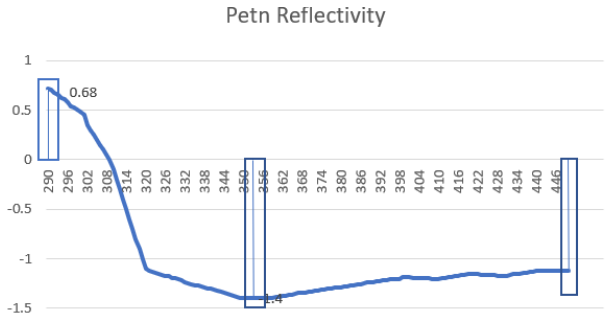


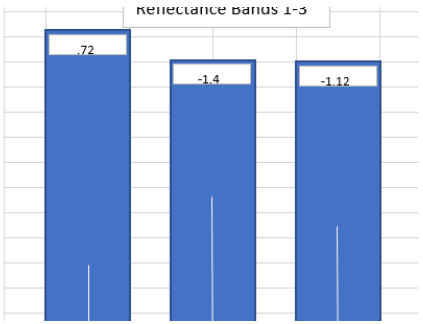




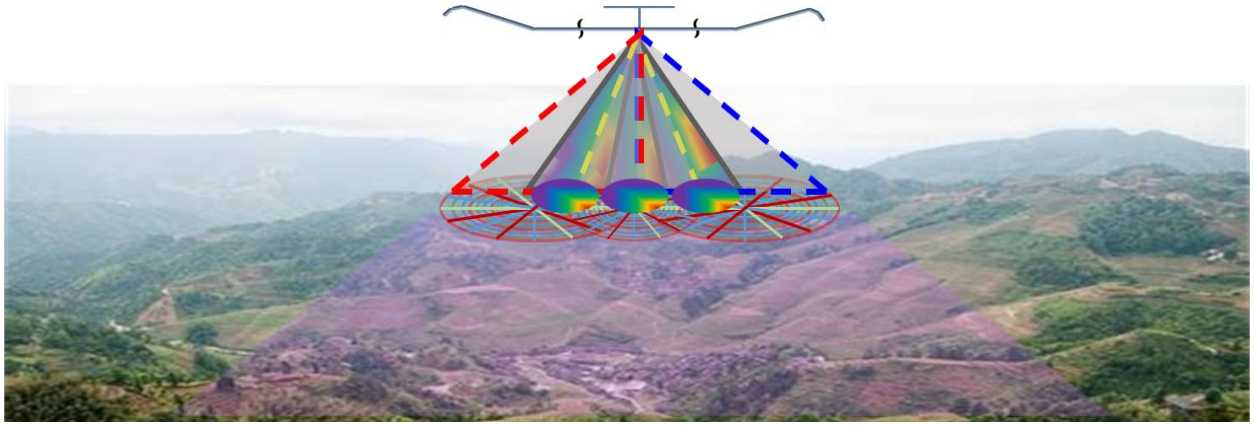


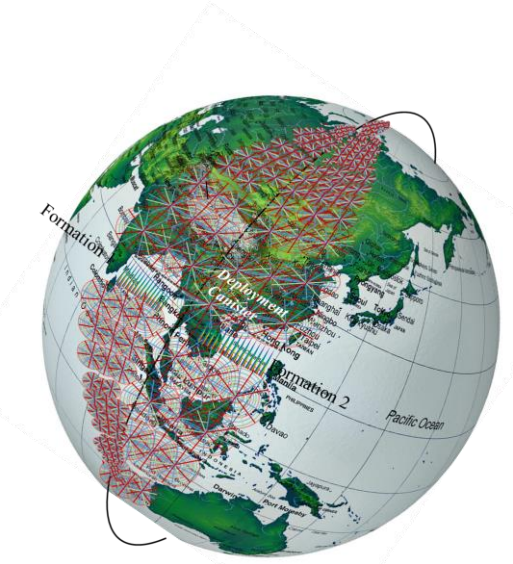






Questions?





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