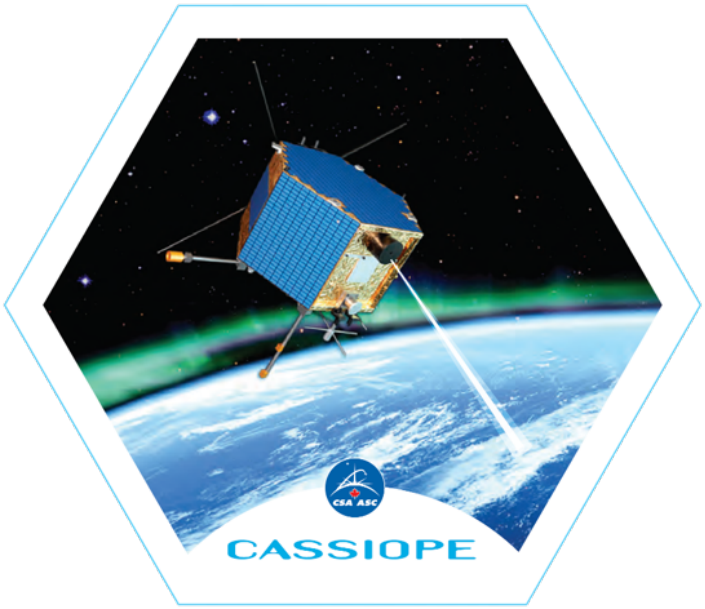
ePOP RRI Observations of Amateur Radio HF Transmissions



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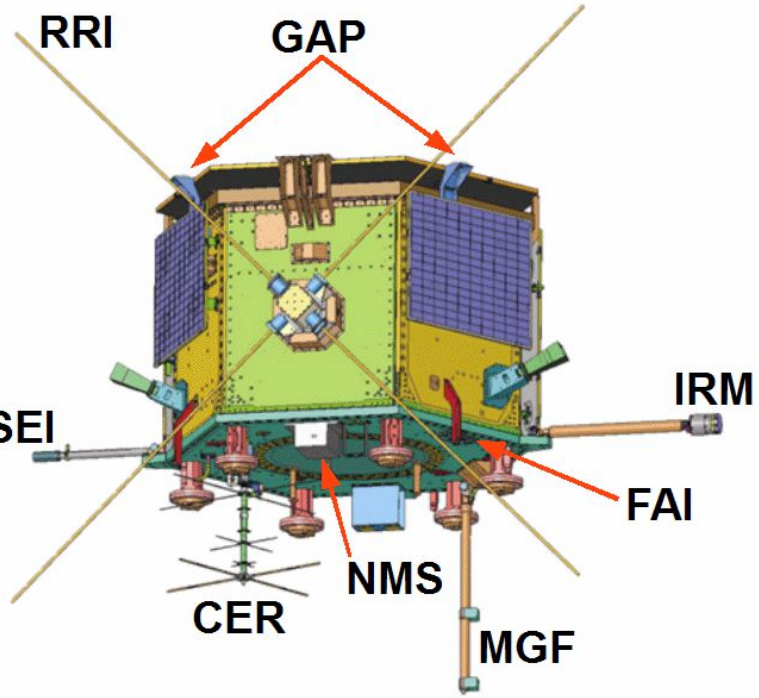
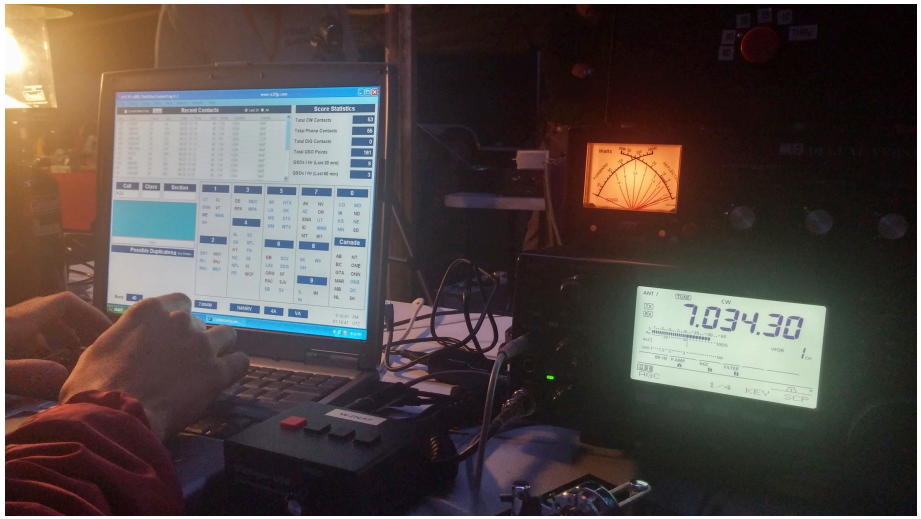
ePOP RRI

The CASSIOPE (CAScade, Smallsat and IOnospheric Polar Explorer) satellite was launched on September 29, 2013 by Spacex's Falcon 9 v 1.1. CASSIOPE is a Canadian designed and built satellite, with two primary tasks: a telecommunications technology demonstration, and a science mission. The latter is carried out by e-POP (the enhanced Polar Outflow Probe), a suite of 8 instruments onboard CASSIOPE, tasked with studying the outflow of plasma from the ionosphere into the near Earth geospace. One of ePOP's 8 instruments, the RRI (Radio Receiver Instrument), measures naturally and artificially generated radio waves between 10 Hz and 18 MHz. It employs 4, 3-m monopole antennas, which are combined to give a cross-dipole configuration. RRI samples at 62.5 kHz on two channels, over a 30 kHz bandwidth. One science target for RRI is to study HF propagation in the ionosphere. It has been used in conjunction with multiple radar facilities located around the world, and we want to test the feasibility of adding the amateur radio community into the mix. We were excited to learn that the ARRL is conducting a field-day, happening at the same time that CASSIOPE is nearing perigee in its orbit. This weekend the spacecraft will be at approximately 375 km altitude, over the continental United States. We have managed to free up a few minutes of time on the satellite and our goals are to: first, determine whether or not we can detect transmissions during the field day, and secondly, decode the transmissions and determine their origin. CASSIOPE is funded by the Canadian Space Agency, and operated by a community of Canadian and American scientists from over a dozen institutions. Its operations headquarters is located at the University of Calgary.



ARRL Field Day

- American Radio Relay League (ARRL)-sponsored amateur radio operating event.
- Objective: Contact as many US or Canadian Stations as Possible in a 24 Hour Period, primarily on HF (3-30 MHz) Bands
- Stations are encouraged to operate remotely to simulate emergency conditions.
- 27 June 2015 1800 UT – 28 June 2015 2059 UT (Always Fourth Full Weekend in June)
- 2687 Stations Participated in 2014 (http://www.arrl.org/results-database?event_id=58360)



CASSIOPE ePOP Trajectory

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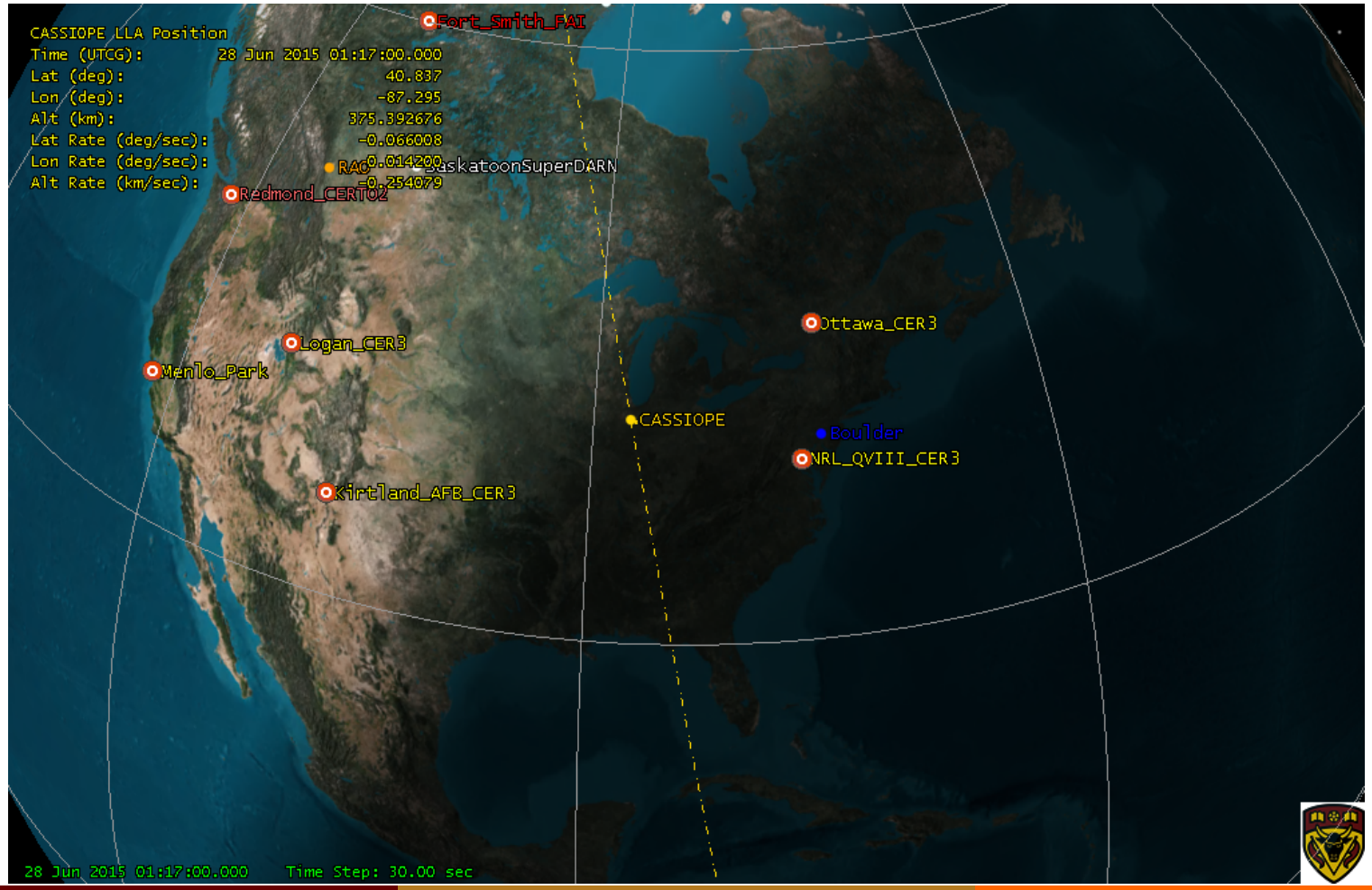
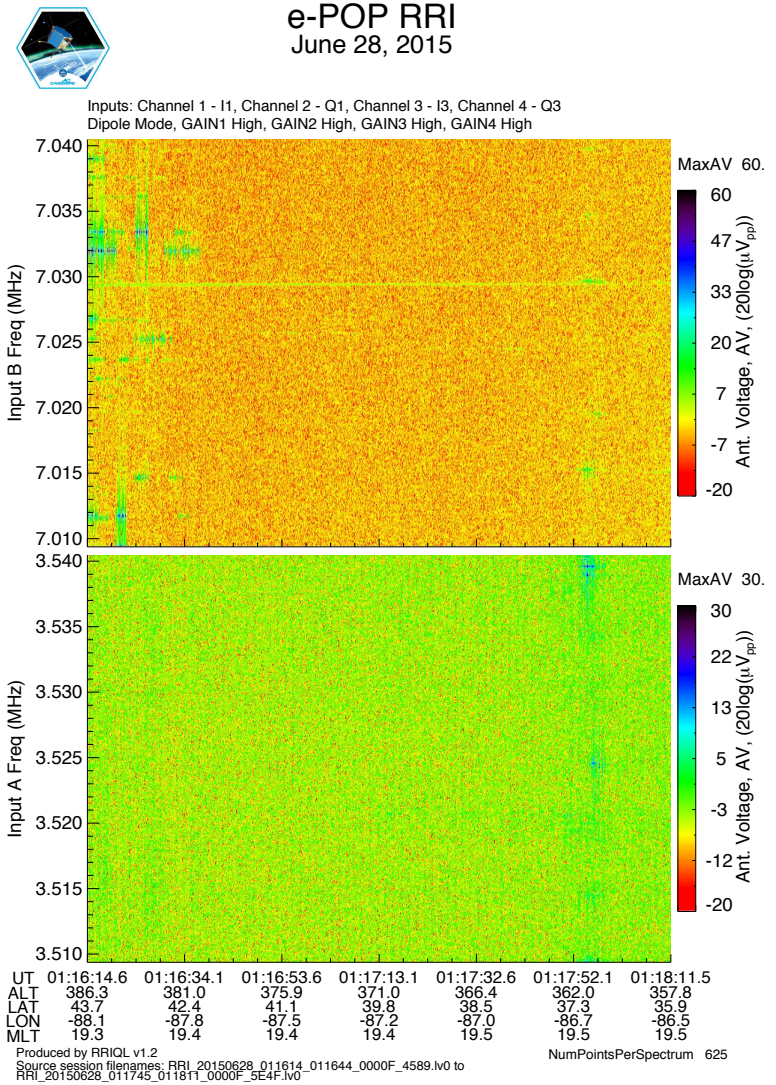
North to South Pass with RRI Receiving from 0116 to 0118 UT 28 June 2015 from 3.510 to 3.540 MHz and 7.010 to 7.040 MHz



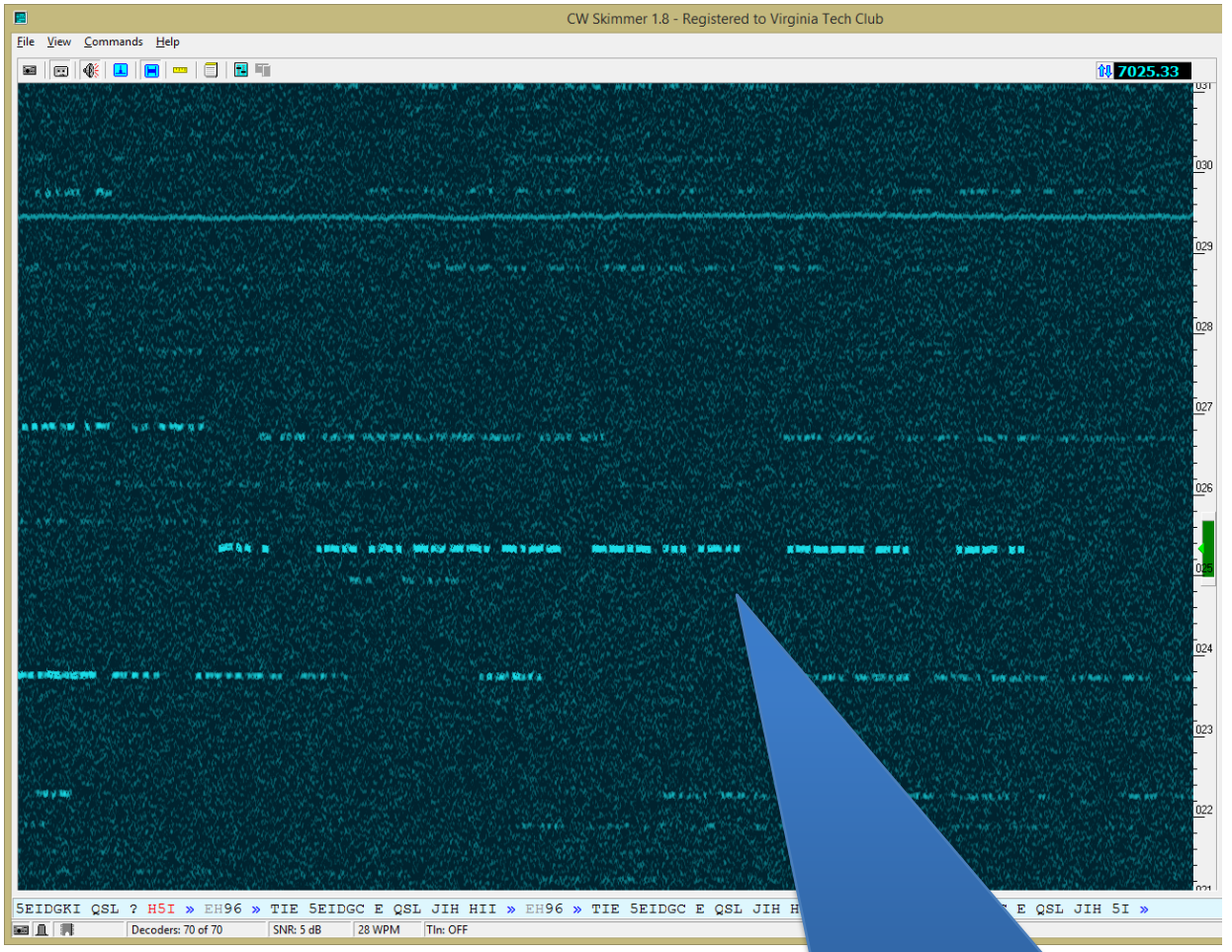
RRI Observations

- Strong signals observed on 7 MHz Band from ~0116:15 – 0116:40 UT (~43.7˚ N to 42.1˚N).
- Signals drop off suddenly after this point.
- Few signals seen in 3.5 MHz band.
- Signals appear again at 0117:52 UT in both 3.5 and 7 MHz.



CW Decoding

- 7 MHz signals decoded aurally
- 23 Stations Identified
- Most from Illinois, Wisconsin, Indiana
- Special WAV File can be played in CW Skimmer



http://www.dxatlas.com/CwSkimmer/

7 MHz CW Decode

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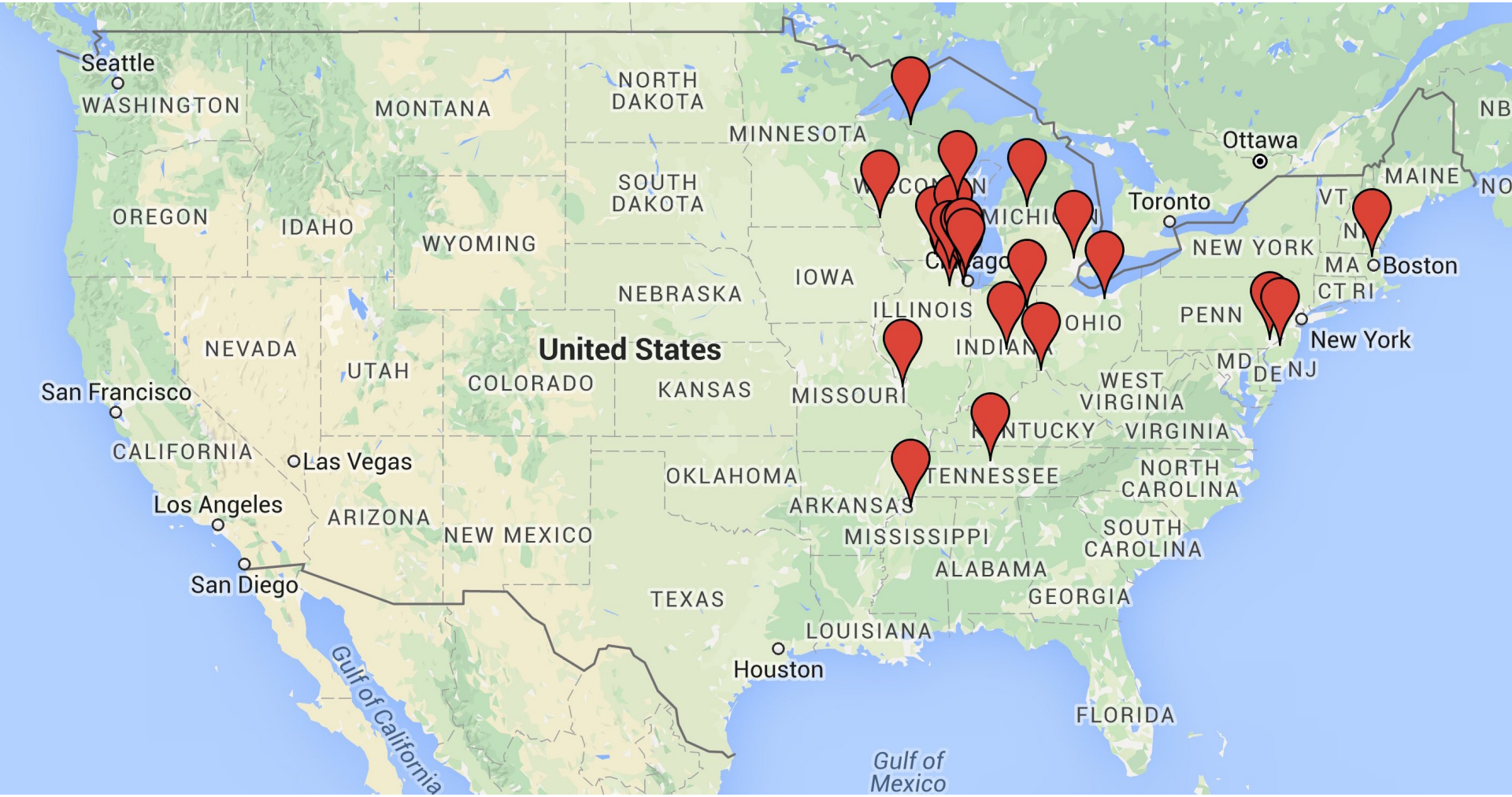

https://www.google.com/maps/d/edit?mid=zOoXJW2oSyUs.kaAuCqAzWRdQ&usp=sharing

7 MHz CW Decode

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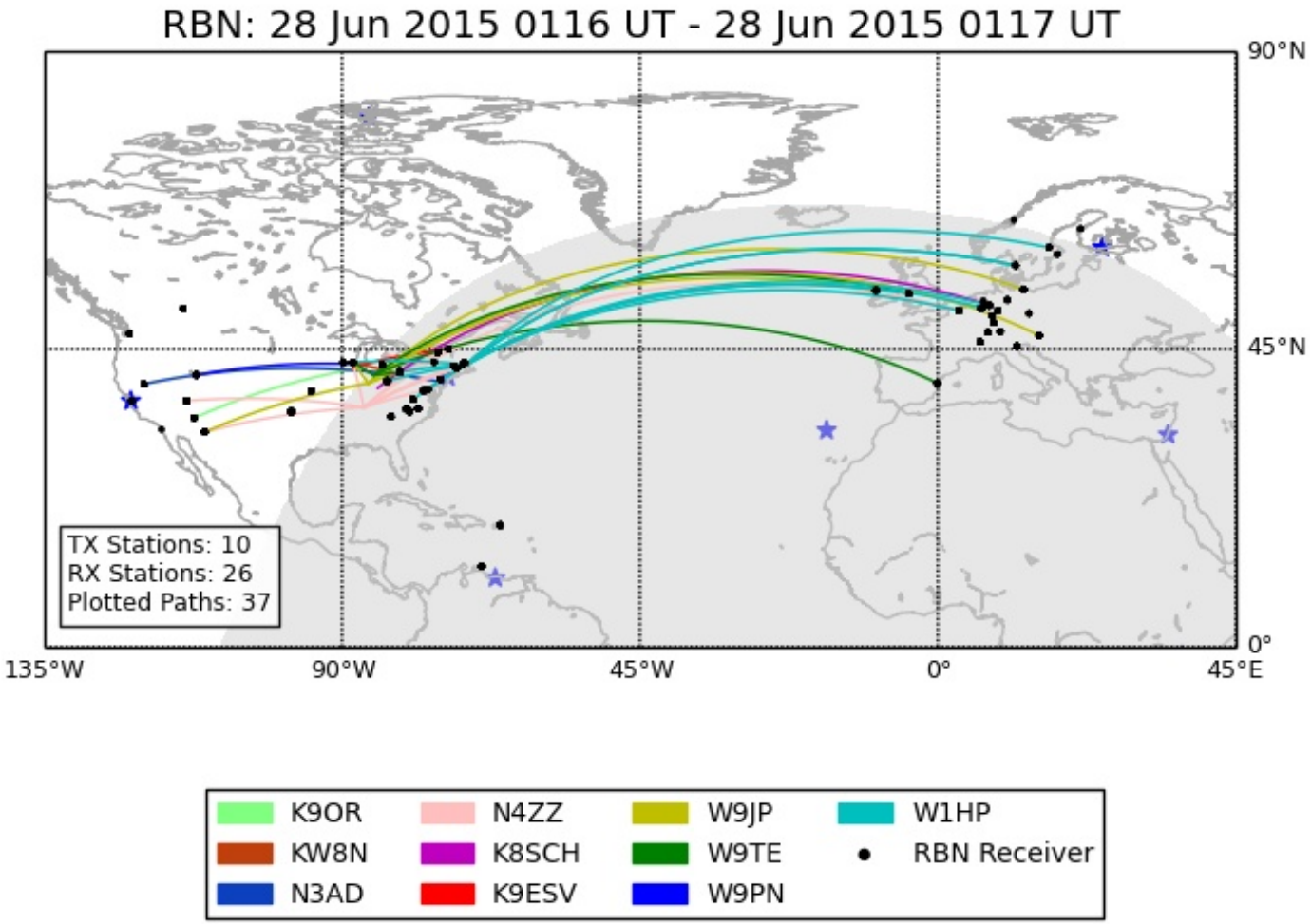
Frequency	Call	Reported Section	QRZ State	Grid	Lat	Lon	Name
7005.18	N4IL	DOESN'T COUNT - STATION IN QSO					Tracy L Melton
7005.58	W1HP	DOESN'T COUNT - STATION IN QSO					
7009.49	W9NE		IL	EN51ts	41.760594	-88.344504	FOX RIVER RADIO LEAGUE INC
7011.38	K8CAD		MI	EN74jc			WEXAUKEE AMATEUR RADIO CLUB
7011.68	W9PN	WI	WI	EN52mr			DOUGLAS R SPEER
7014.53	W9MVA		WI	EN43jt	43.831719	-91.17135	MISSISSIPPI VALLEY AMATEUR RADIO ASSO
7022.27	W9TE		IN	EN71jb	41.054182	-85.241697	FORT WAYNE RADIO CLUB
7025.33	WR9Y	WI	WI	EN53va			RICHARD BARCZ
7026.76	W9JP	IN	IN	EM69xt	39.802959	-86.019672	INDIANAPOLIS RADIO CLUB
7026.76	W9SW	IL	IL	EN61cu			CHICAGO SUBURBAN RADIO ASSOCIATION
7032.5	K9EAM	WI	WI	EN54xi			GREEN BAY MIKE AND KEY CLUB INC
7032.55	W0SRC		MO	EM48uo	38.586076	-90.295323	ST LOUIS AND SUBURBAN RADIO CLUB
7033.49	K9ESV		IL	EN52tg			McHenry County RACES Association
7033.49	WB6FDY		IL			EN62ag	RONALD S LISIECKI
7036.1	K8SCH		OH	EM79qc			OH KY IN AMATEUR RADIO SOCIETY INC
7036.1	N9EZ		MI	EN56al			John A Forslund
7037.64	N4ZZ	TN	TN	EM66pe			DONALD H BINKLEY
7039.05	N9SAB		IL	EN62ci	42.372264	-87.830369	Timothy P Ortiz
7039.67	N3AD		PA	FN20ib			ALAN J DONZIGER
7040.67	KW8N		OH	EN81xi			ROBERT B HAYES
7043.39	K8ED		MI	EN82io	42.606733	-83.328708	MARK SHAW
7044.83	K9OR		IL	EN62da	42.030327	-87.688909	RANDALL B BROTHERS
7044.83	K2MK	Very faint; only identified because K9OR gave call	NJ	FM29nw	39.939637	-74.881503	Michael H Kravitz

Reverse Beacon Network

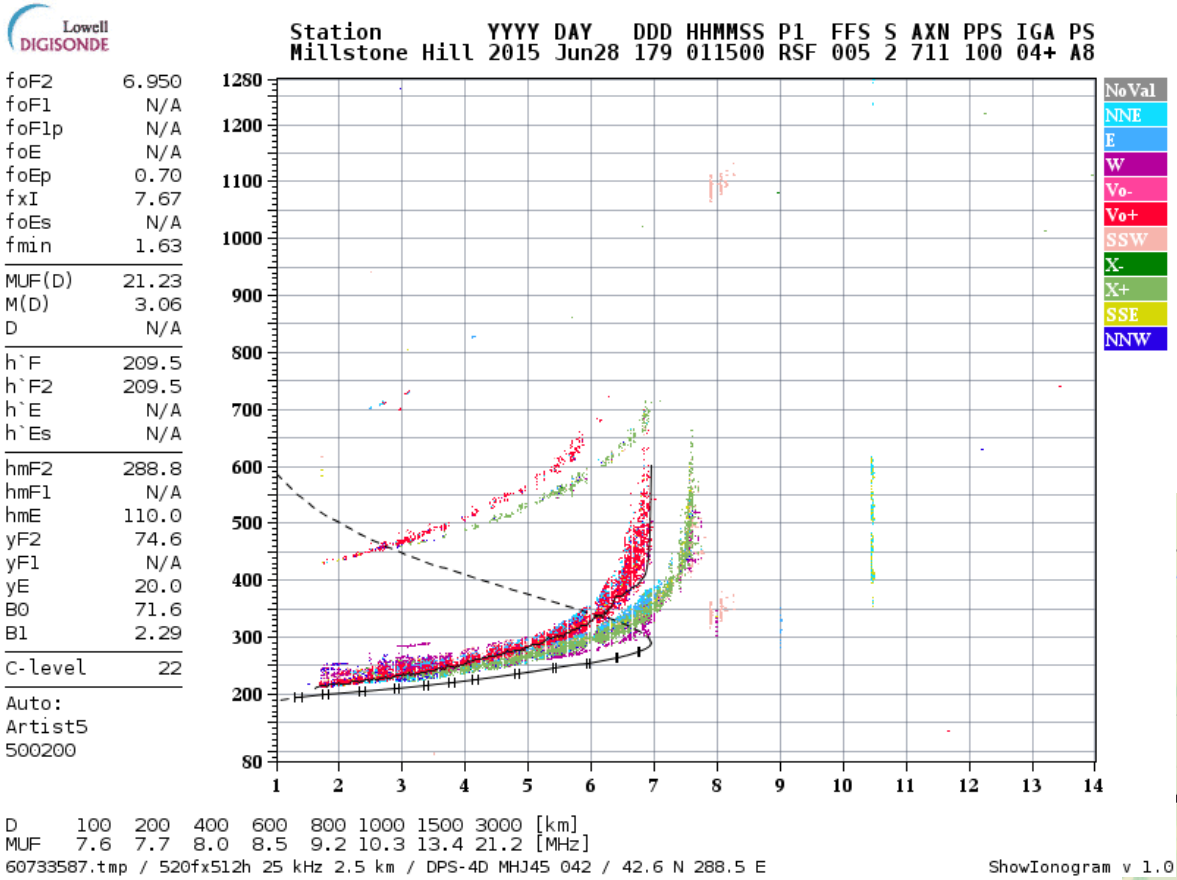


- During the 2 minute pass, 10 of the ePOP identified transmitters were spotted by 26 RBN receivers.
- Plotted RBN receivers without paths were active during the 2 minutes, but did not spot the ePOP identified stations.

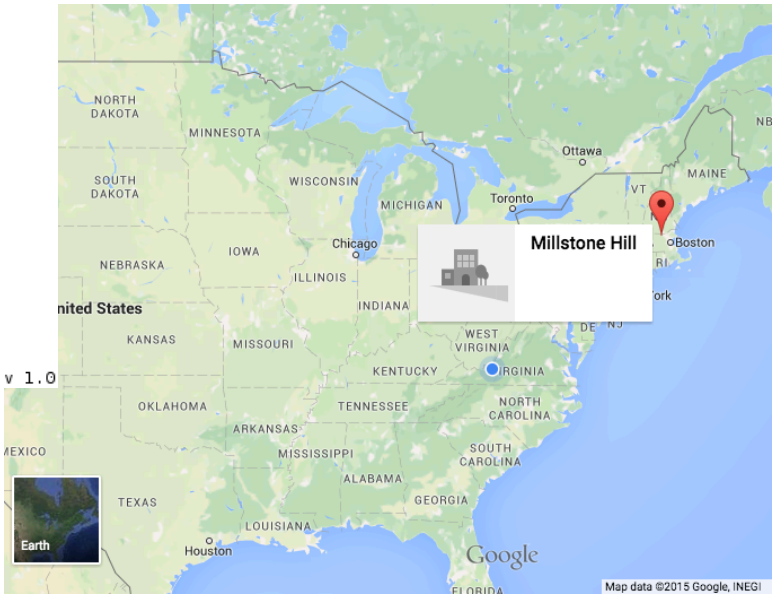
Maximum Plasma Frequency

- The plasma frequency is proportional to the square root of the ionospheric electron density.
- If the satellite flies above an ionospheric layer with a plasma frequency higher than the HF signals transmitted from the ground, the signals will be shielded from the satellite.
- We believe the satellite passes through a region of increases plasma density and frequency. When the plasma frequency of all ionospheric layers below the satellite is lower than 7 MHz, signals are observed. Once the satellite passes to a region where a lower altitude ionospheric layer has a plasma frequency greater than 7 MHz, the signals are shielded.

Millstone Hill Ionogram

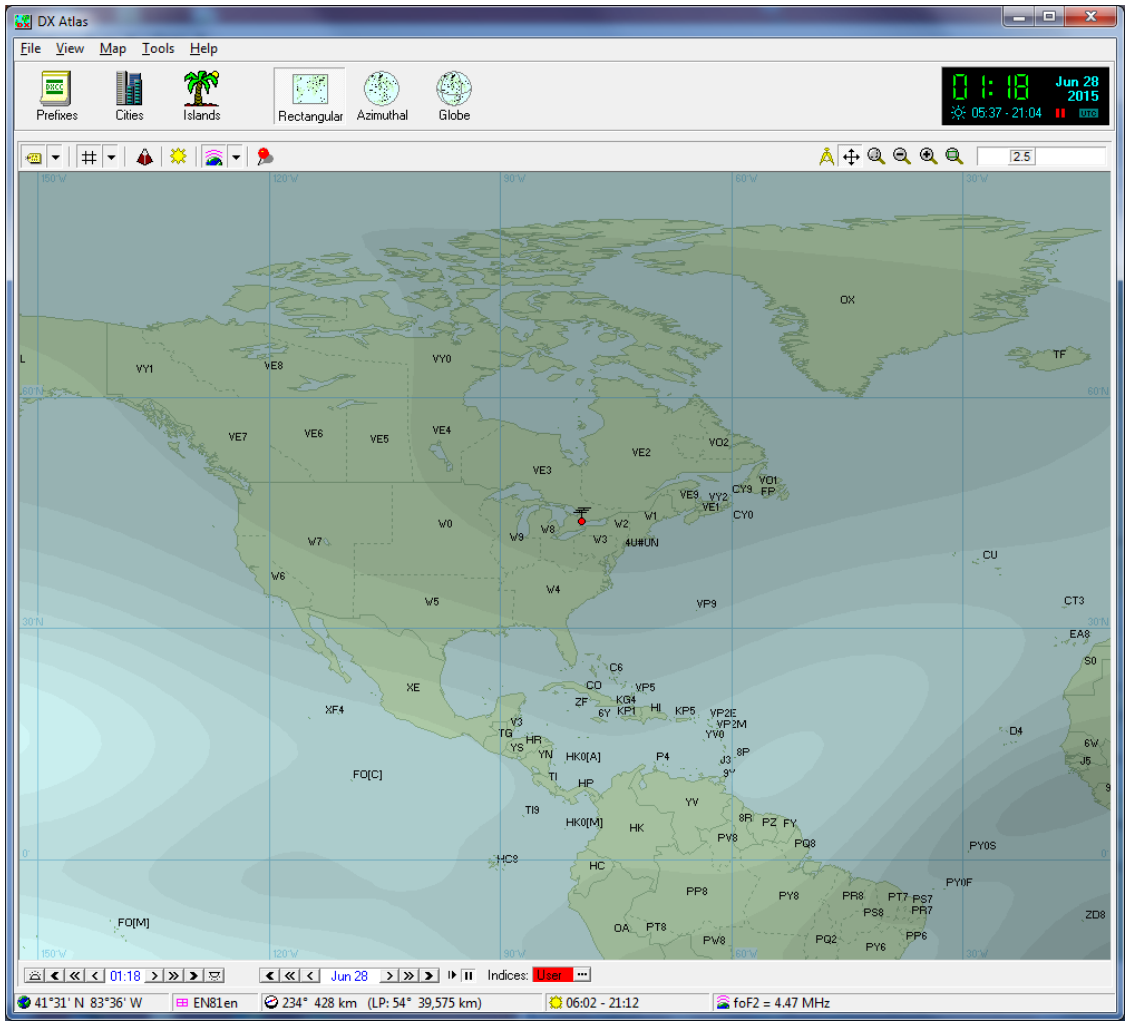


- FoF2 = 6.950 MHz at Millstone Hill at 0115 UT, which is close to CASSIOPE trajectory.
- Additional, nearby ionosonde data is not currently available.



Source: http://umlcar.uml.edu/DIDBase/
[*Reinisch and Galkin*, 2011]

IRI 2000 Modeled FoF2 Map



- A quick-look DX Atlas/International Reference Ionosphere (IRI) 2000 [*Bilitza*, 2001] Prediction of FoF2 shows a positive FoF2 gradient along the satellite trajectory.
- This supports the plasma frequency filtering hypothesis.

http://www.dxatlas.com/DxAtlas/

Summary and Conclusions

- The RRI Instrument on CASSIOPE Satellite listened to radio frequencies in the 3.5 and 7 MHz amateur radio bands during a large-scale operating event on 28 June 2015.
- The RRI could successfully detect amateur radio transmissions at 7 MHz, but they ended abruptly after approximately 20 seconds.
- This data suggests that the satellite moved into a region where an ionospheric layer below the satellite had a plasma frequency greater than 7 MHz, thereby shielding incoming signals.
- Additional modeling and analysis work should be completed to further support this conclusion.
- This experiment demonstrates the feasibility of conducting further HF amateur radio-satellite coordinated studies.

Ackowledgements

- RRI and CASSIOPE/ePOP are funded by the Canadian Space Agency. CASSIOPE is operated by a community of Canadian and US scientists from more than a dozen institutions. Its operations headquarters is located at the University of Calgary
- The authors acknowledge B. W. Reinisch of the University of Massachusetts Lowell for making these ionogram images available.

References

Bilitza, D. (2001), International Reference Ionosphere 2000, Radio Sci., 36(2), 261–275, doi:10.1029/2000RS002432.

Reinisch, B. W., and I. A. Galkin, Global ionospheric radio observatory (GIRO), Earth, Planets, and Space, 63, 377-381, doi:10.5047/eps.2011.03.001, 2011.