W4UVA SATELLITE GROUND STATION PROJECT

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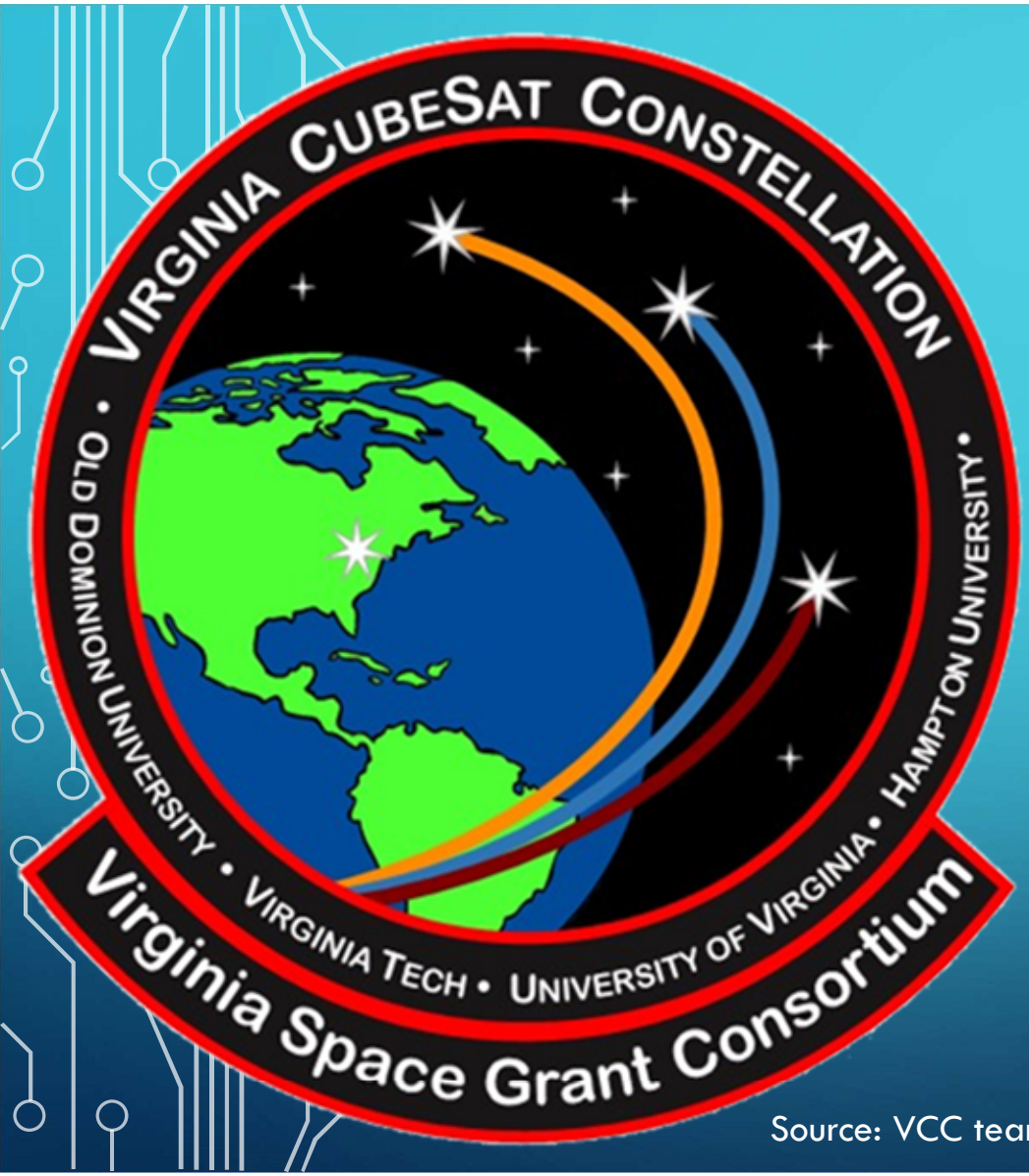
W4UVA TRUSTEE

11 APRIL 2017

THE W4UVA PROJECT…

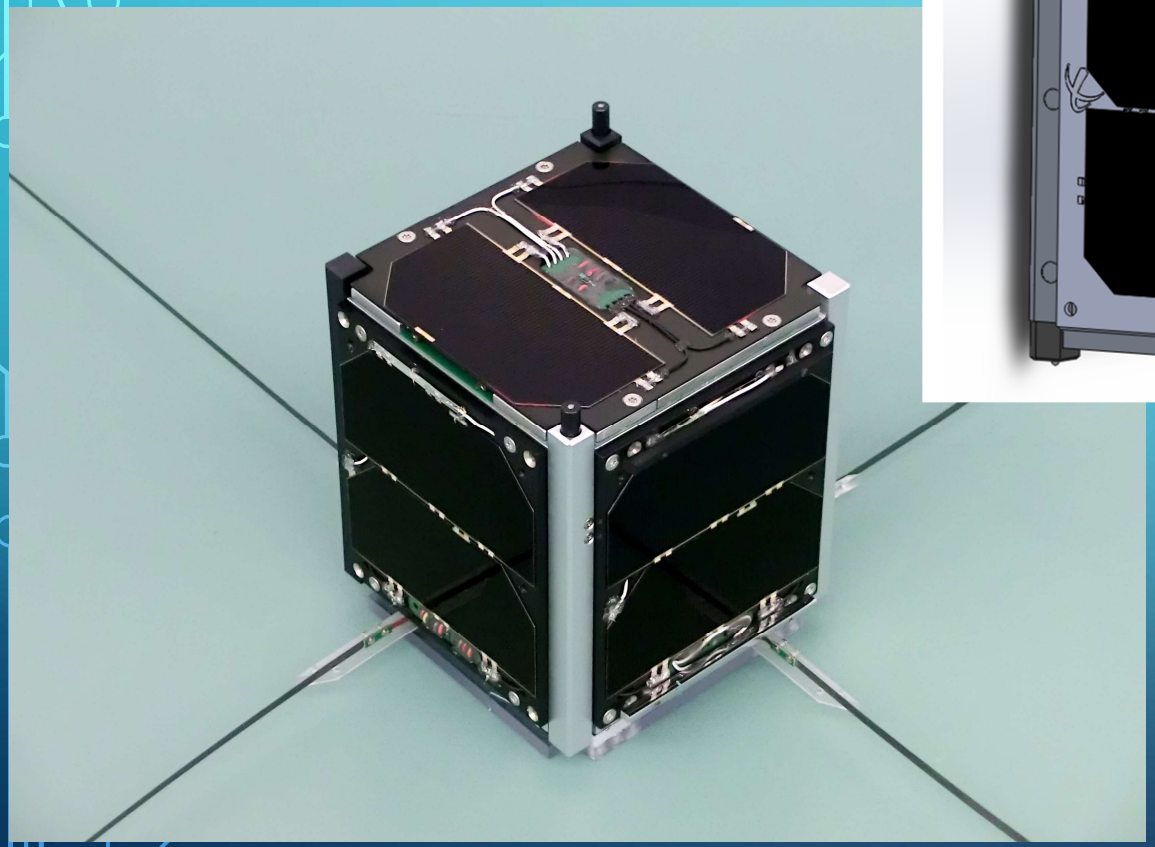
- Design, build, and operate two amateur radio satellite ground stations at the University of Virginia



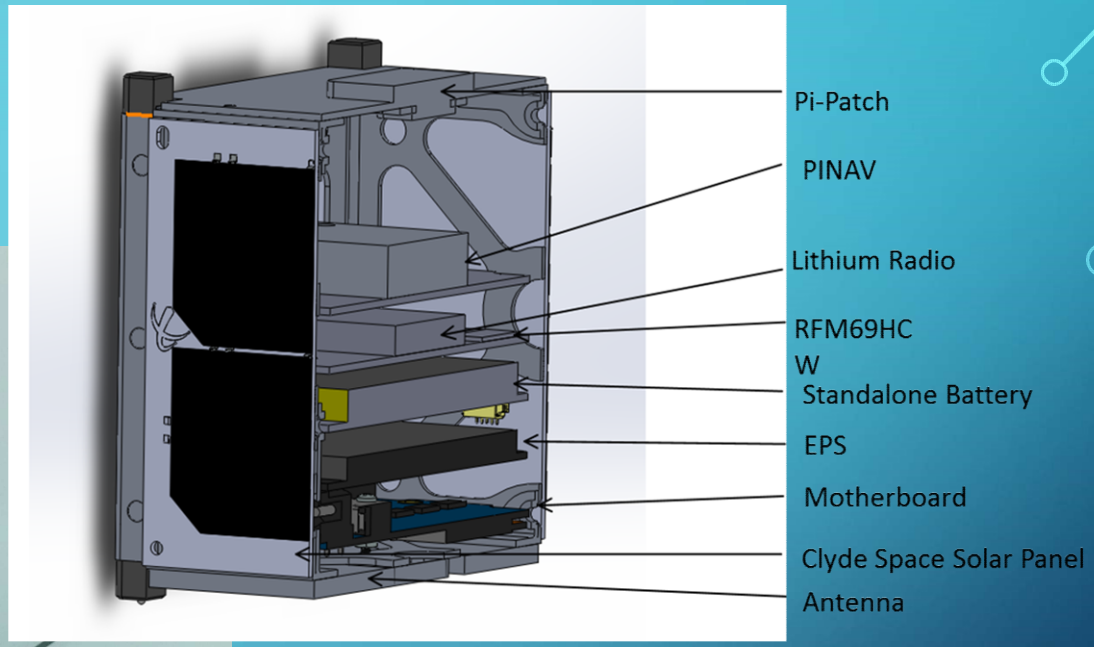
WHY ARE WE BUILDING THESE GROUND STATIONS?

- ODU, VT, UVa, Hampton plan to launch a constellation of three 1U cubesats in Spring 2018.

Source: VCC team



Source: AMSAT-UK



Source: VCC team

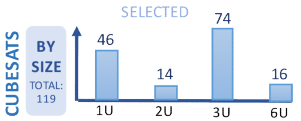
National Aeronautics and Space Administration

NASA'S CUBESAT LAUNCH INITIATIVE (CSLI)

CUBESATS are small research spacecraft called nanosatellites, built to standard dimensions of 10x10x11 cm.

CSLI provides opportunities for small satellite payloads to fly on upcoming launches to NASA Centers, educational & non-profit organizations.

less than **3 lbs.** CubeSat sizes are in standard 10X10X11 cm units, or U: 1U, 2U, 3U, or 6U, usually weighing less than 3 lbs per U. This is about the weight of a half gallon of milk!



8 YEARS

- Proof of Concept 2008
- 1st Initiative: 2010
- 8th Initiative 2016

49 LAUNCHED CUBESATS IN 46 MISSIONS

152 CUBESAT MISSIONS SELECTED

74% of those selected have been offered a launch

85 UNIQUE ORGANIZATIONS

68 UNIVERSITIES

38 STATES SELECTED TO LAUNCH A CUBESAT

400 Pre-K – 8 students built the 1st CubeSat deployed into space by an elementary school in May 2016.

PAYLOAD FOCUS AREAS

64% Technology Demonstration

51% Scientific Research

57% Education

go.nasa.gov/CubeSat_initiative

Source: NASA

National Aeronautics and Space Administration

NASA'S CUBESAT LAUNCH INITIATIVE (CSLI)

CSLI:

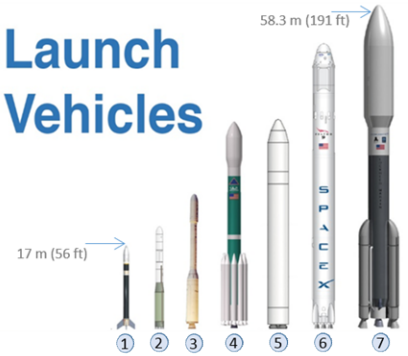
- **PROMOTES** innovative public-private technology partnerships
- **FACILITATES** low-cost technology development
- **STRENGTHENS** NASA and the Nation's future workforce

Educational
Launch of
Nanosatellites

Missions

22 ELaNA
98 CubeSat

Launch Vehicles



1. SUPER STRYPI
2. MINOTAUR I
3. TAURUS XL
4. DELTA II
5. ANTARES
6. FALCON 9
7. ATLAS V

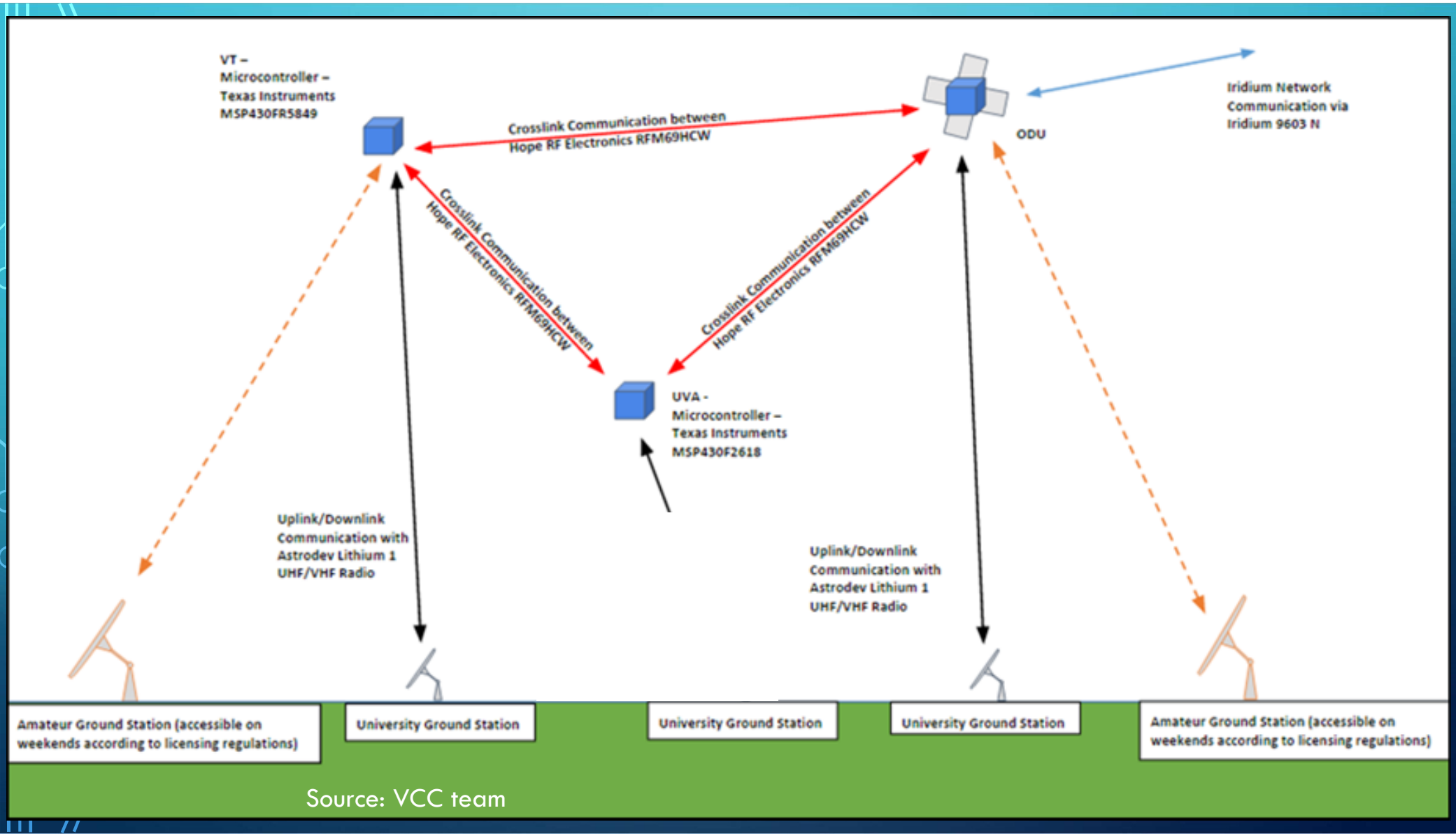
LAUNCH PROVIDERS

	A	B	C	D	E	F	TOTAL BY STATUS
MANIFESTED	5	0	2	2	12	31	52
LAUNCHED	11	13	11	7	4	0	46
TOTAL BY PROVIDER	16	13	13	9	16	31	98

A. NASA B. National Reconnaissance Office C. United States Air Force D. Commercial Expendable Launch Vehicle
E. Commercial from International Space Station F. Venture Class Launch Services (Firefly Space Systems, Rocket Lab USA, Virgin Galactic)

go.nasa.gov/CubeSat_initiative

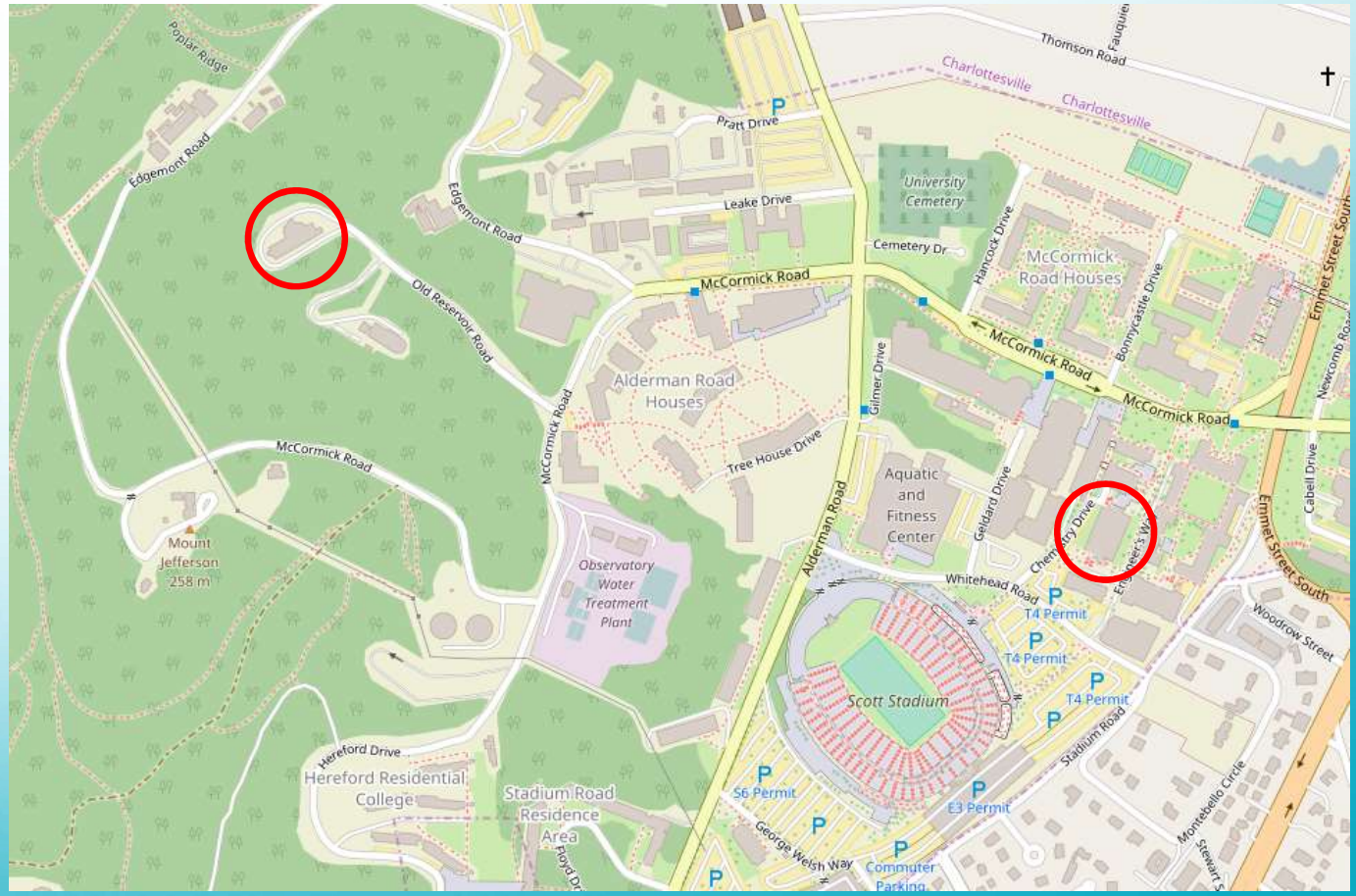
Source: NASA



Source: VCC team

BUT WE ALREADY HAVE TWO GROUND STATIONS!

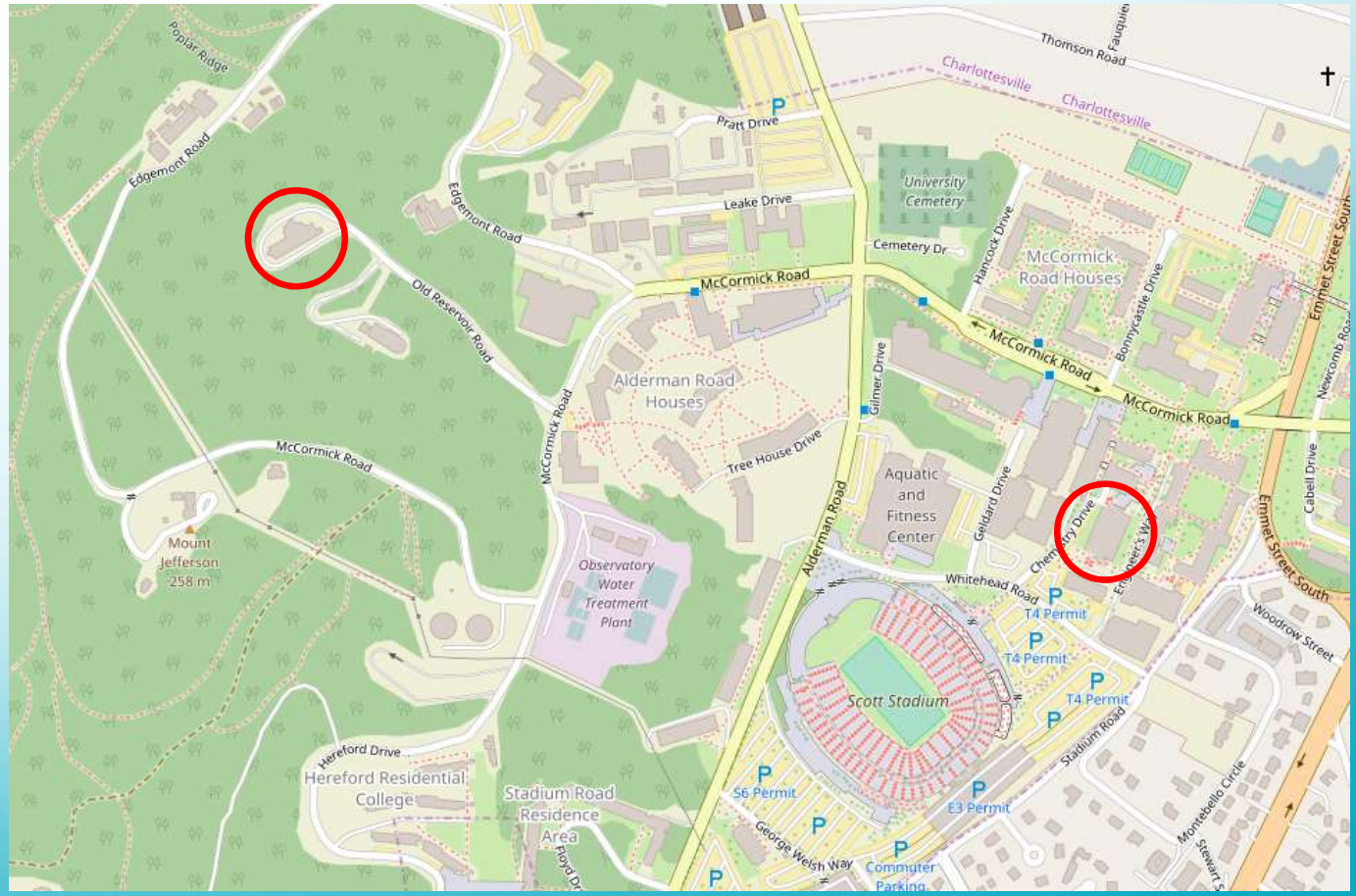
- Yes, but UVa doesn't have one!



Source: OpenStreetMap

BUT WE ALREADY HAVE TWO GROUND STATIONS!

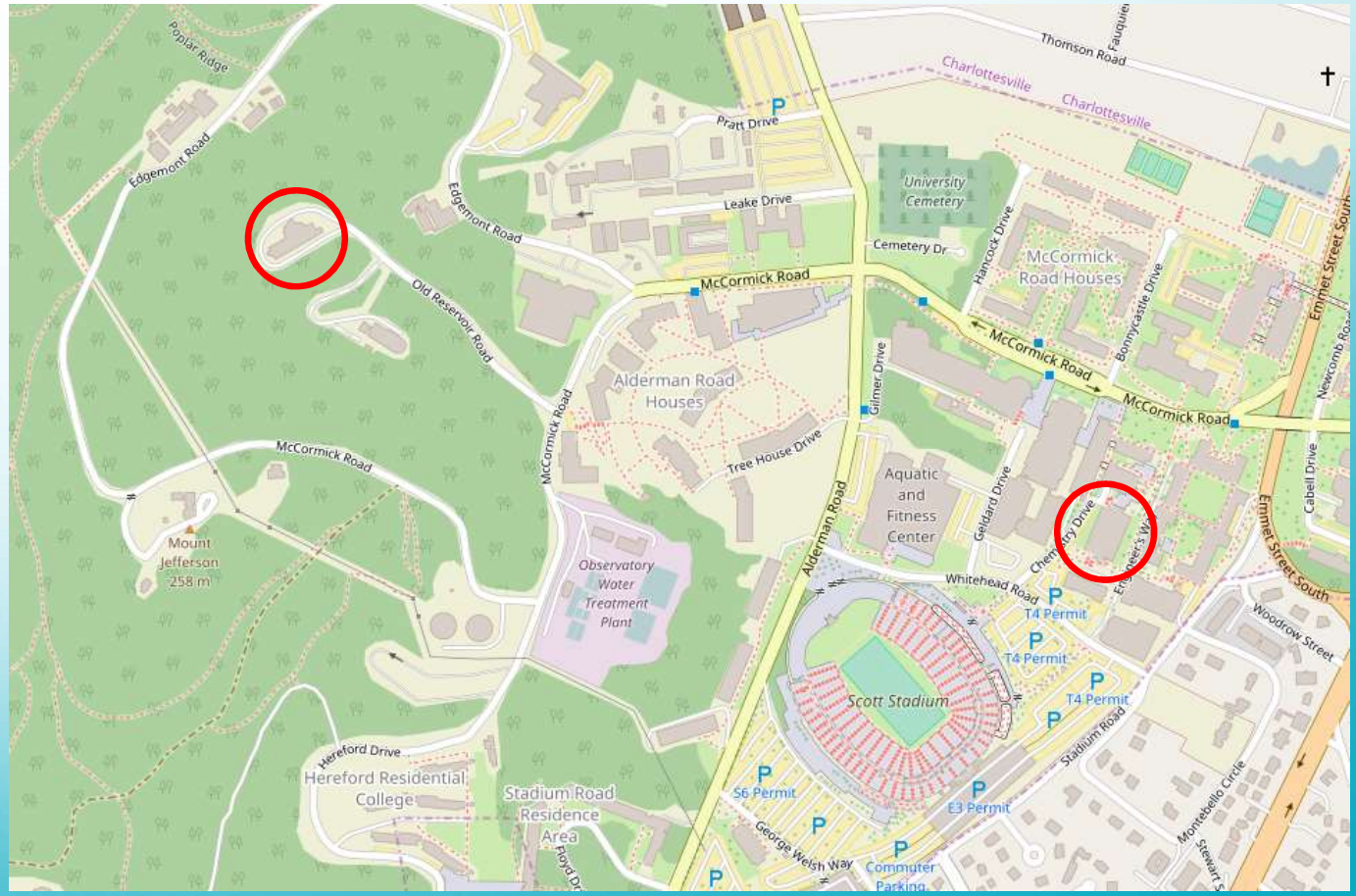
- The three satellites will fly as a constellation, all overhead at the same time. We'll need one ground station per satellite to downlink the maximum data.



Source: OpenStreetMap

BUT WE ALREADY HAVE TWO GROUND STATIONS!

- We're building two:
  - The primary on the roof of the Mechanical Engineering Building will handle the mission-critical command, control, and downlink functions on a day-to-day basis.
  - The secondary at the W4UVA station will act as backup, and will be the platform for R&D.



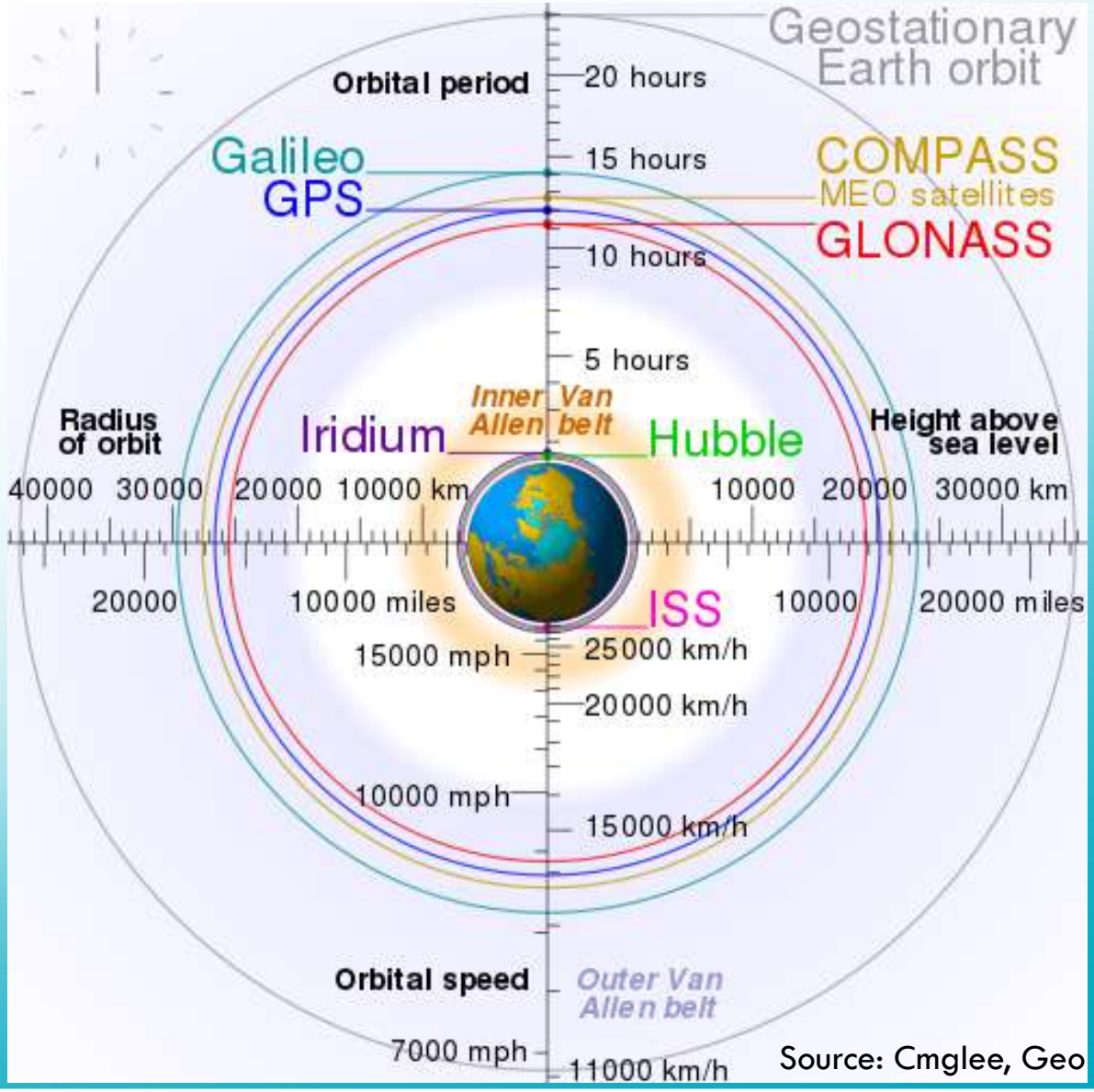
Source: OpenStreetMap

WHAT GOES INTO A SATELLITE GROUND STATION?

- The ability to:
  - Predict satellite passes and track satellite from horizon to horizon
  - Schedule and transmit (uplink) command and control packets to satellite
  - Receive (downlink) data from satellite
  - Decode, distribute, and archive downlinked data
  - Keep a detailed log of all communications with satellite

TYPES OF ORBITS

- Low Earth Orbit (LEO)
- Medium Earth Orbit (MEO)
- Geosynchronous Orbit (GEO)
- Geostationary Orbit (GSO)
- High Earth Orbit (HEO)



Source: Cmglee, Geo Swan

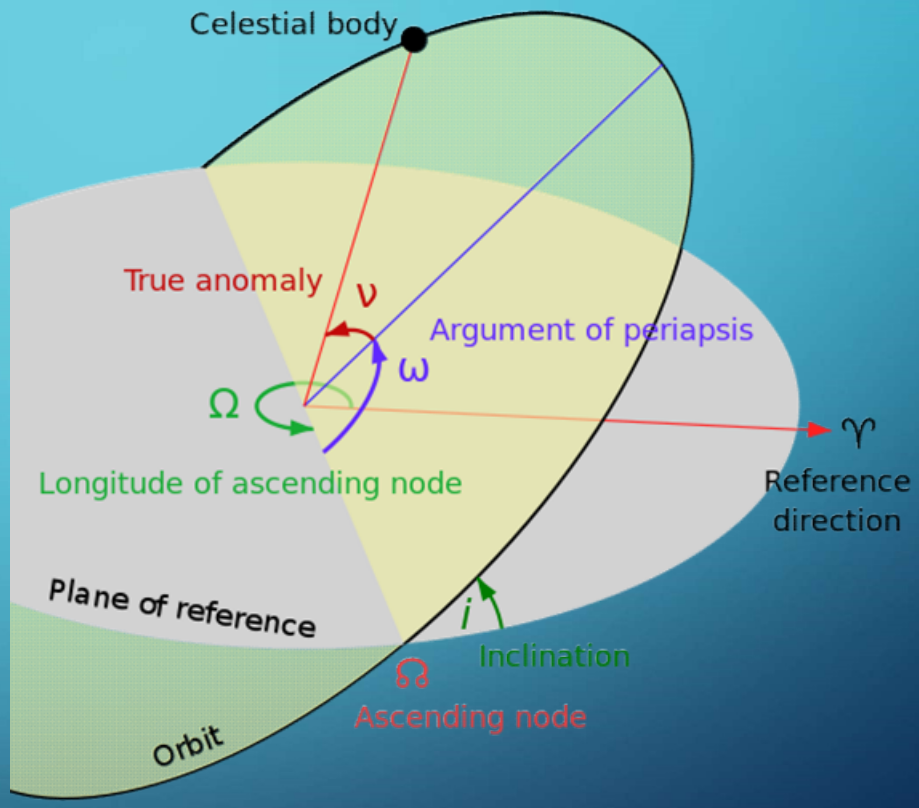
ORBITAL ELEMENTS

Most common representation for amateur radio use is the Two-Line Element (TLE)

FUNCUBE-1 (AO-73)

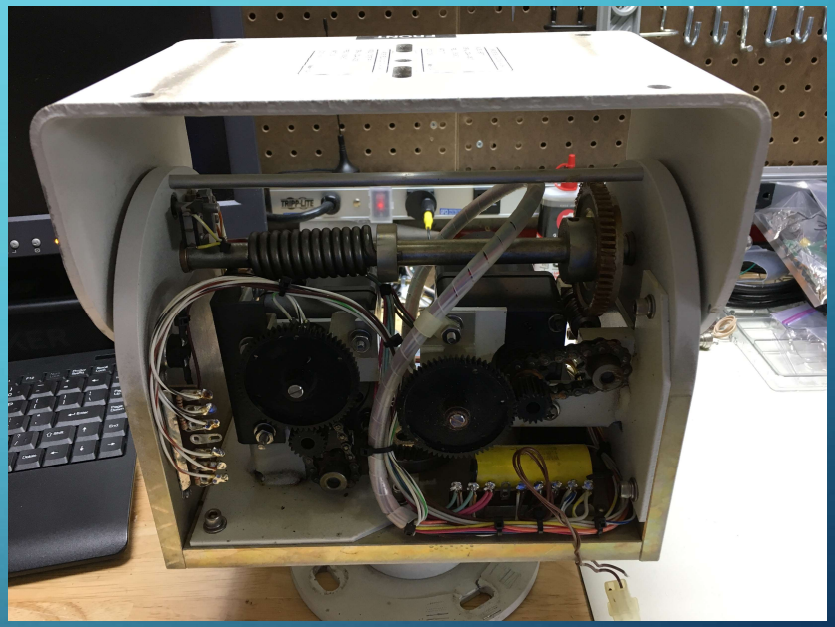
1 39444U 13066AE
17099.92006044 .00000404
00000-0 56548-4 0 9991

2 39444 97.6391 146.4119
0059890 129.4690 231.1843
14.81380738180913



Source: Lasunncty at the English language Wikipedia

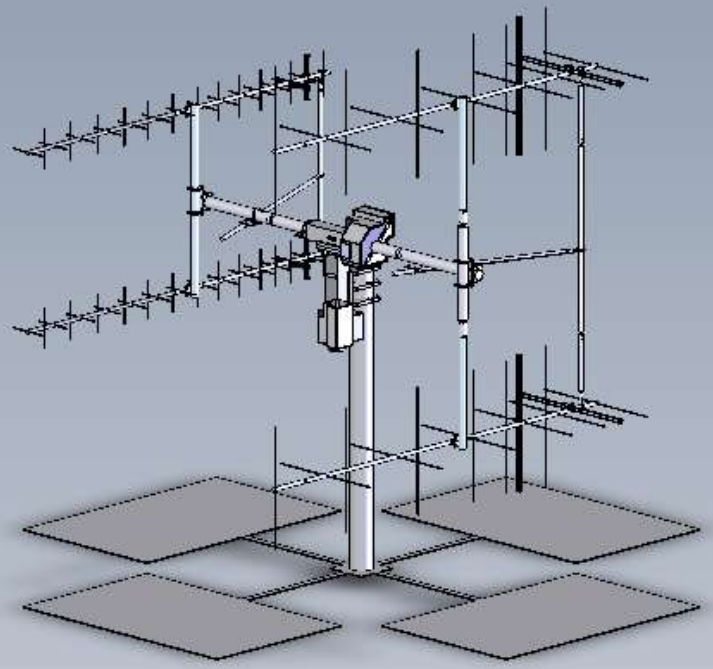
Source: Alfa Radio



Source: KQ9P

NOW THAT WE KNOW WHERE TO POINT…

- Amateur Satellite Service frequency allocations in most amateur radio bands, but 2m and 70cm are still the most commonly used
- Congestion caused by the large number of cubesats (along with advances in MMICs) is pushing satellites to higher frequency bands



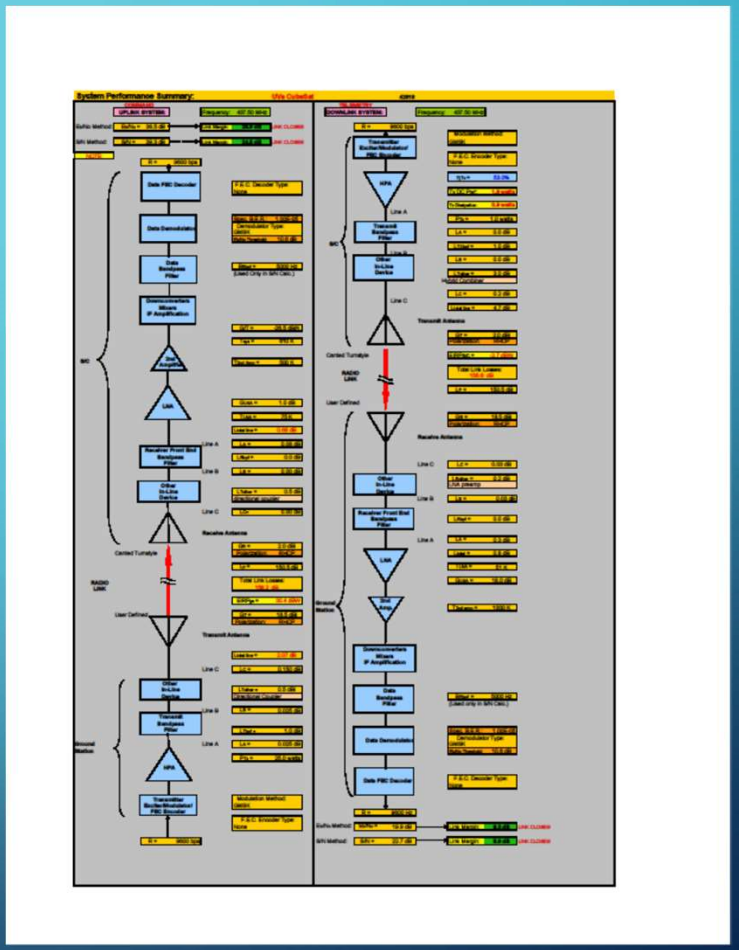
Source: M2 Antennas

SOFTWARE DEFINED RADIO (SDR) DC - 6 GHZ

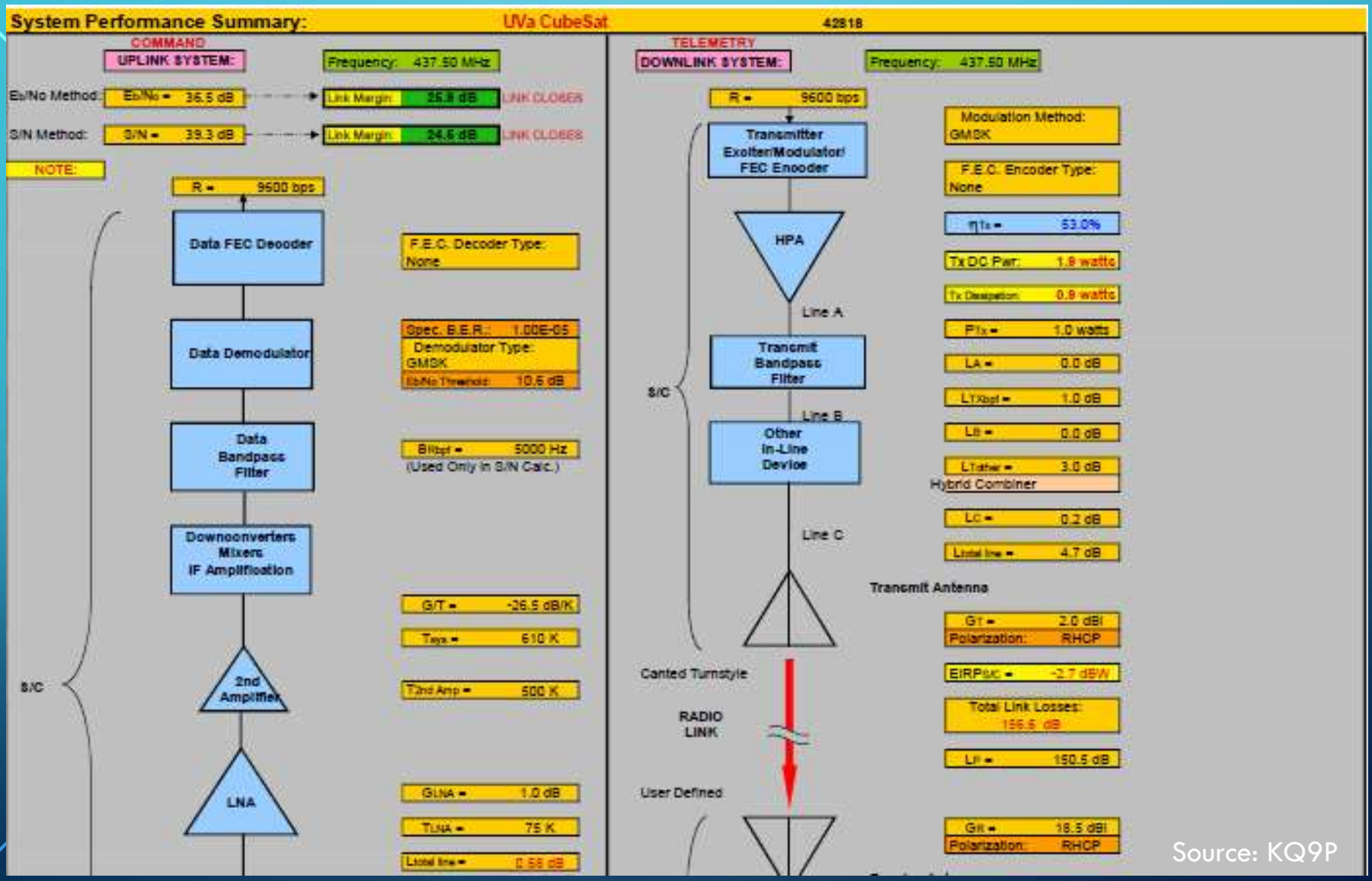
Source: Ettus Research

ADDING IT ALL UP: THE LINK BUDGET

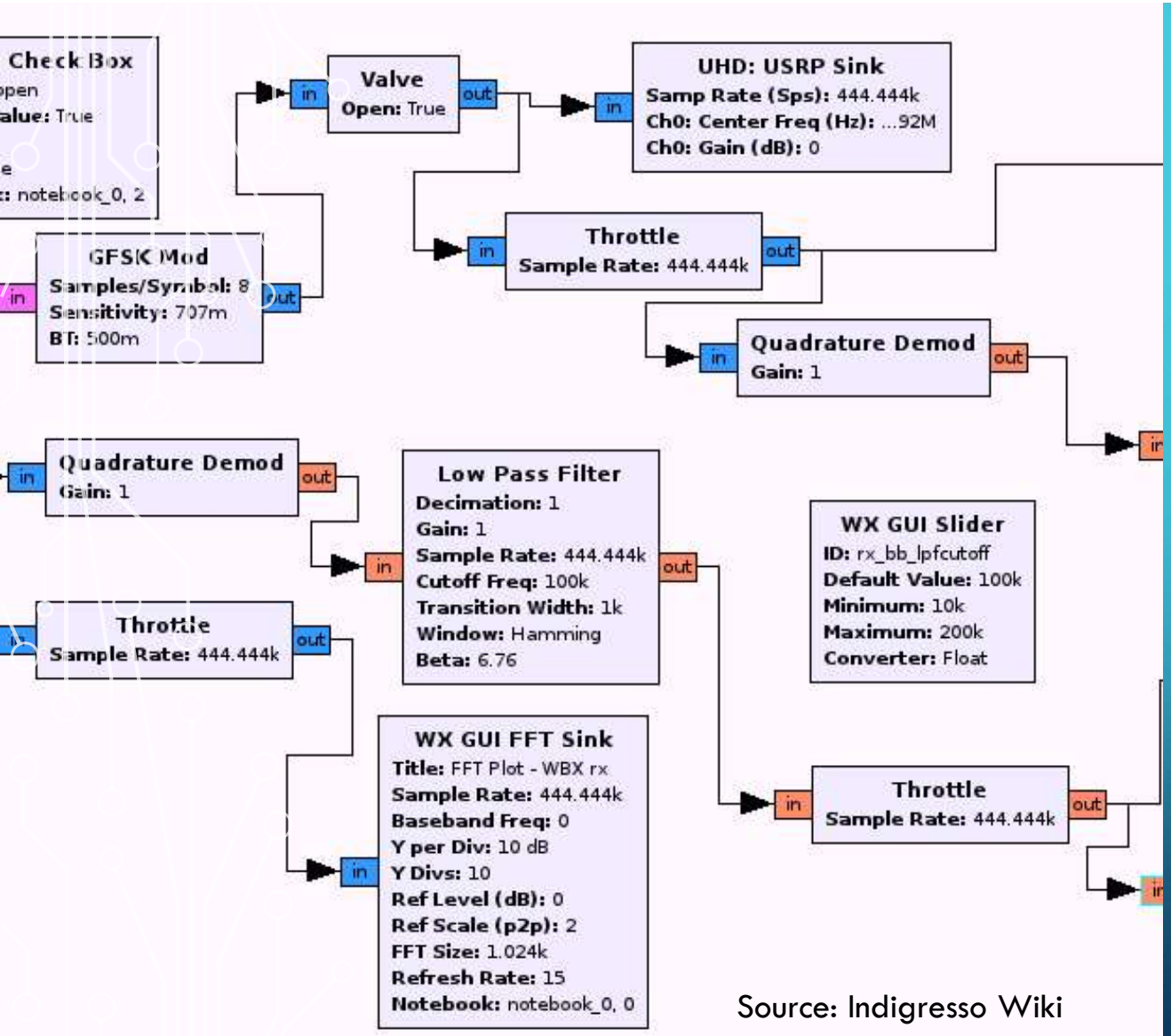
- Essential to understand whether we will be able to communicate with our satellite
- Calculate gain or loss attributable to every component (both artificial and natural) between the antenna connector on the satellite radio and the antenna connector on the ground station radio



Source: KQ9P


System Performance Summary:
UVa CubeSat
42818
COMMAND
UPLINK SYSTEM:
Frequency: 437.50 MHz
Eb/No Method:
Eb/No = 36.5 dB
Link Margin: 25.9 dB
LINK CLOSES
S/N Method:
S/N = 39.3 dB
Link Margin: 24.6 dB
LINK CLOSES
NOTE:
R = 9600 bps
Data FEC Decoder
F.E.C. Decoder Type:
None
Data Demodulator
Spec. B.E.R.: 1.00E-05
Demodulator Type:
GMSK
Eb/No Threshold: 10.6 dB
Data
Bandpass
Filter
Bfbpf = 5000 Hz
(Used Only in S/N Calc.)
Downconverters
Mixers
IF Amplification
G/T = -26.5 dB/K
Tsys = 610 K
2nd
Amplifier
T2nd Amp = 500 K
LNA
GLNA = 1.0 dB
TLNA = 75 K
Lcoax line = 0.59 dB
S/C
TELEMETRY
DOWNLINK SYSTEM:
Frequency: 437.50 MHz
R = 9600 bps
Transmitter
Exciter/Modulator/
FEC Encoder
Modulation Method:
GMSK
F.E.C. Encoder Type:
None
HPA
ηTx = 53.0%
Tx DC Pwr: 1.9 watts
Tx Dissipation: 0.9 watts
Line A
Transmit
Bandpass
Filter
PTx = 1.0 watts
LA = 0.0 dB
LTXbpf = 1.0 dB
S/C
Line B
Other
In-Line
Device
LB = 0.0 dB
LTether = 3.0 dB
Hybrid Combiner
Line C
LC = 0.2 dB
Lcoax line = 4.7 dB
Transmit Antenna
GT = 2.0 dBi
Polarization: RHCP
Canted Turnstyle
EIRPsat = -2.7 dBW
RADIO
LINK
Total Link Losses:
156.5 dB
LP = 150.5 dB
User Defined
GR = 18.5 dBi
Polarization: RHCP

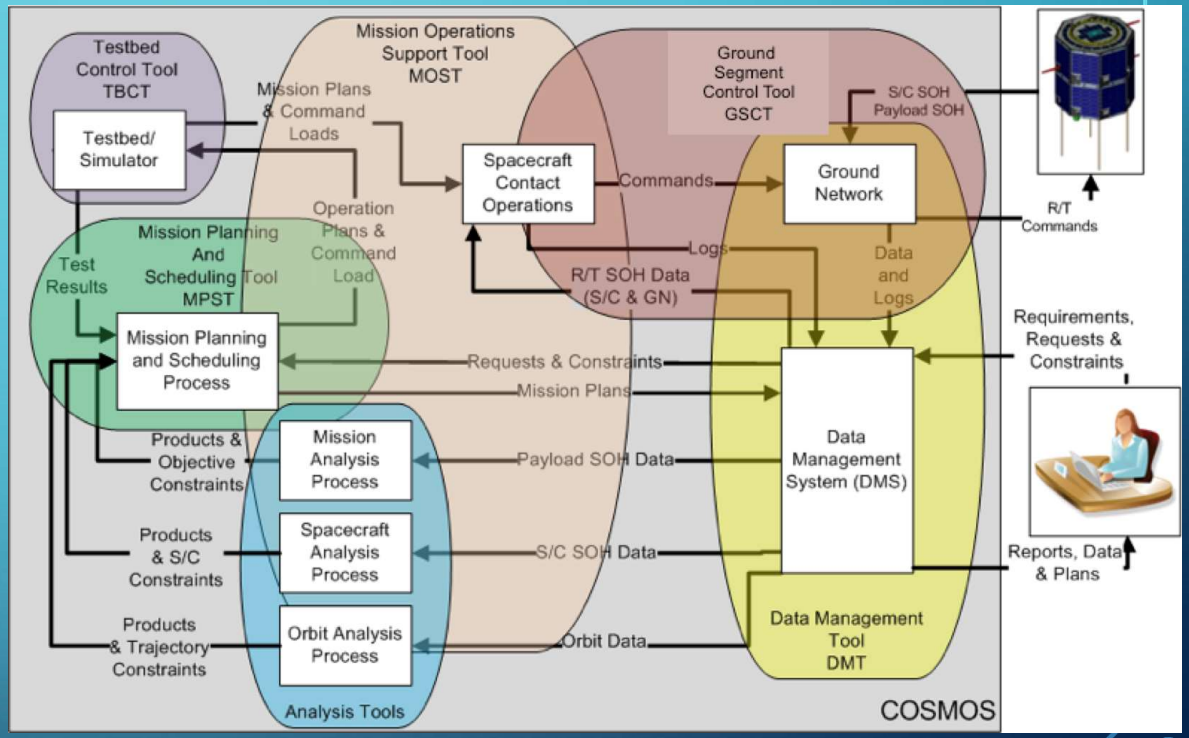
Source: KQ9P



Source: Indigresso Wiki

GNU RADIO OPEN SOURCE PROGRAMMING ENVIRONMENT FOR SDR

COSMOS PROJECT OPEN SOURCE GROUND STATION SOFTWARE



Source: COSMOS Project

FOLLOW THE W4UVA GROUND STATION PROJECT

www.w4uva.org

THANKS FOR YOUR ATTENTION!

MIKE MCPHERSON, KQ9P

W4UVA TRUSTEE

MIKE@KQ9P.US