



PCSat2 / MISSE5 An External ISS Communications Opportunity

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U.S. Naval Academy

6 Dec 2002



In Montreal April 2002

External ISS Communications Experiment

21 Mar 2002.
WE4APR

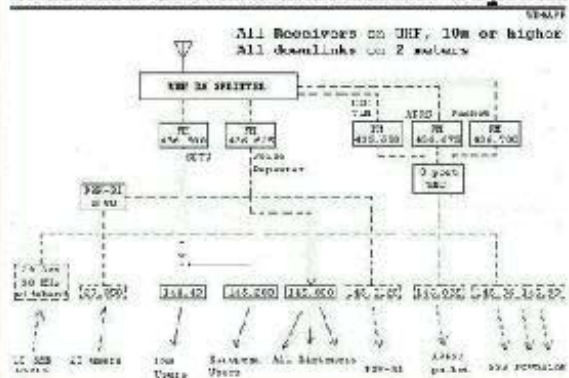
21 March 2002

- ✱ Joint NASA/USNA (Naval Academy(DOD) experiment
- ✱ An external payload experiment for communication exterior to the station
- ✱ The primary mission is to provide a communications link for amateur radio operators and youth
- ✱ To maximize the use of simple and inexpensive available user equipment, and link budget and optimum frequency usage.

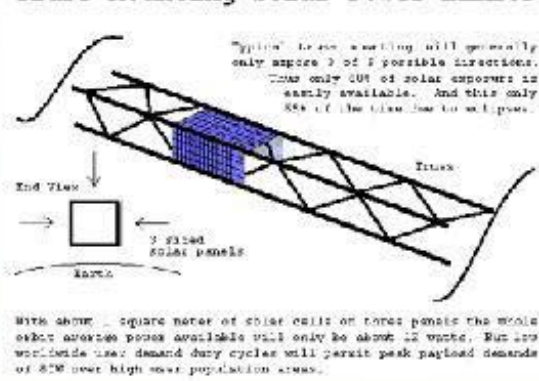
5 Transponders

FM, Packet, SSTV, PSK-31, SSB

External ISS Communications Payload



Truss Mounting Solar Power Limits





DOD Committee Results

External ISS Communications Experiment

21 Mar 2002,
NE44PR

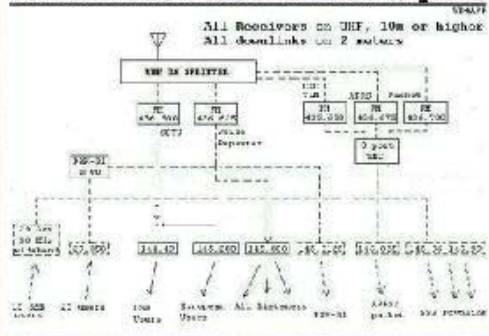
21 March 2002

- * Joint NASA/USNA (Naval Academy(DOD) experiment
- * An external payload attached to the international space station exterior
- * The primary mission is education and outreach to schools, and youth
- * To maximize the outreach potential, the plan features the use of simple and inexpensive available user equipment, and link budget and optimum frequency usage.

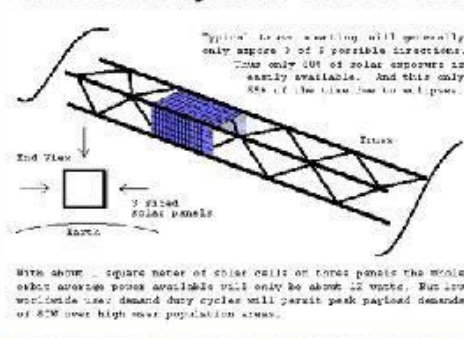
= #34/35

Almost
Last

External ISS Communications Payload



Truss Mounting Solar Power Limits



Almost
Forgotten



November ... An Opportunity

Project

Objective:

To deploy the experiment early on the ISS to enable exposure during solar maximum, as the previous deployment was during solar minimum.

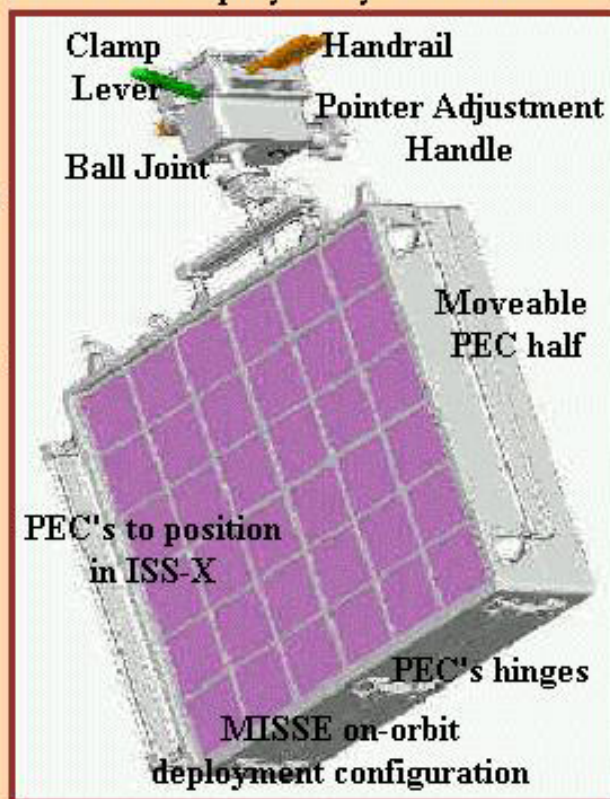
Project Goal:

The project will be able to receive information on the effects of the

MISSE is a reflight of two reusable Passive Experiment Containers (PECs) previously flown on Russian Space Station Mir (STS76/STS86). The PEC's are deployed by EVA and attached to exterior handrails with clamp/pointer assembly.

A PEC consists of various passive sample trays, carousels, and plates, as well as vacuum ultraviolet diodes and an atomic-oxygen pinhole camera.

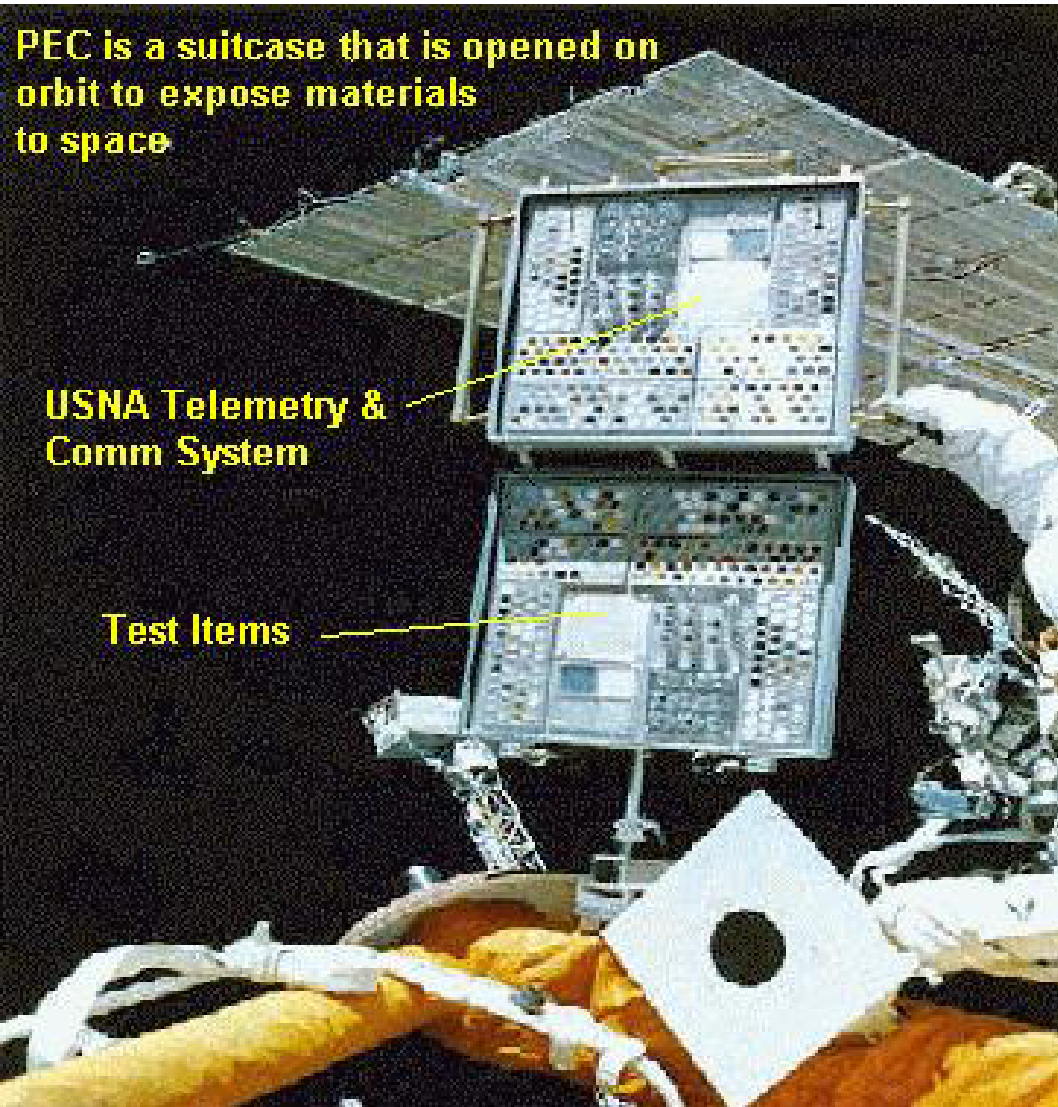
The PEC is opened by the EVA crewman to expose experiments on opposite sides and is oriented to view Ram/Wake, Port/Stbd or Zenith/Nadir. The PEC deployed assembly and experiment





PCsat2 – PEC – MISSE5

PEC is a suitcase that is opened on orbit to expose materials to space



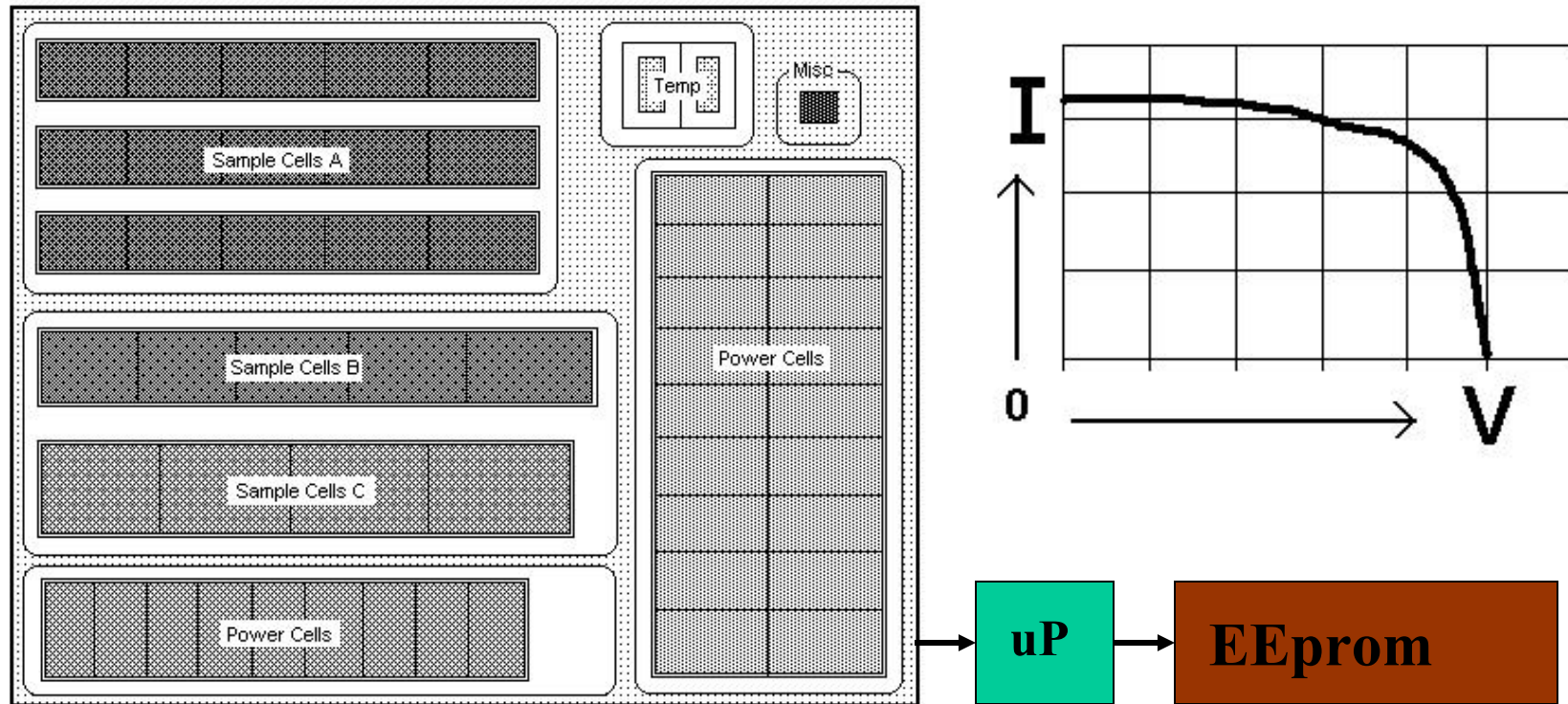
USNA Telemetry & Comm System

Test Items

- MISSE5 is a passive External ISS payload
- It flew on MIR as “MEEP”
- PCsat2 is an Amateur Radio Communications payload Opportunity
- Schedule is TIGHT!



Solar Cell Experiment



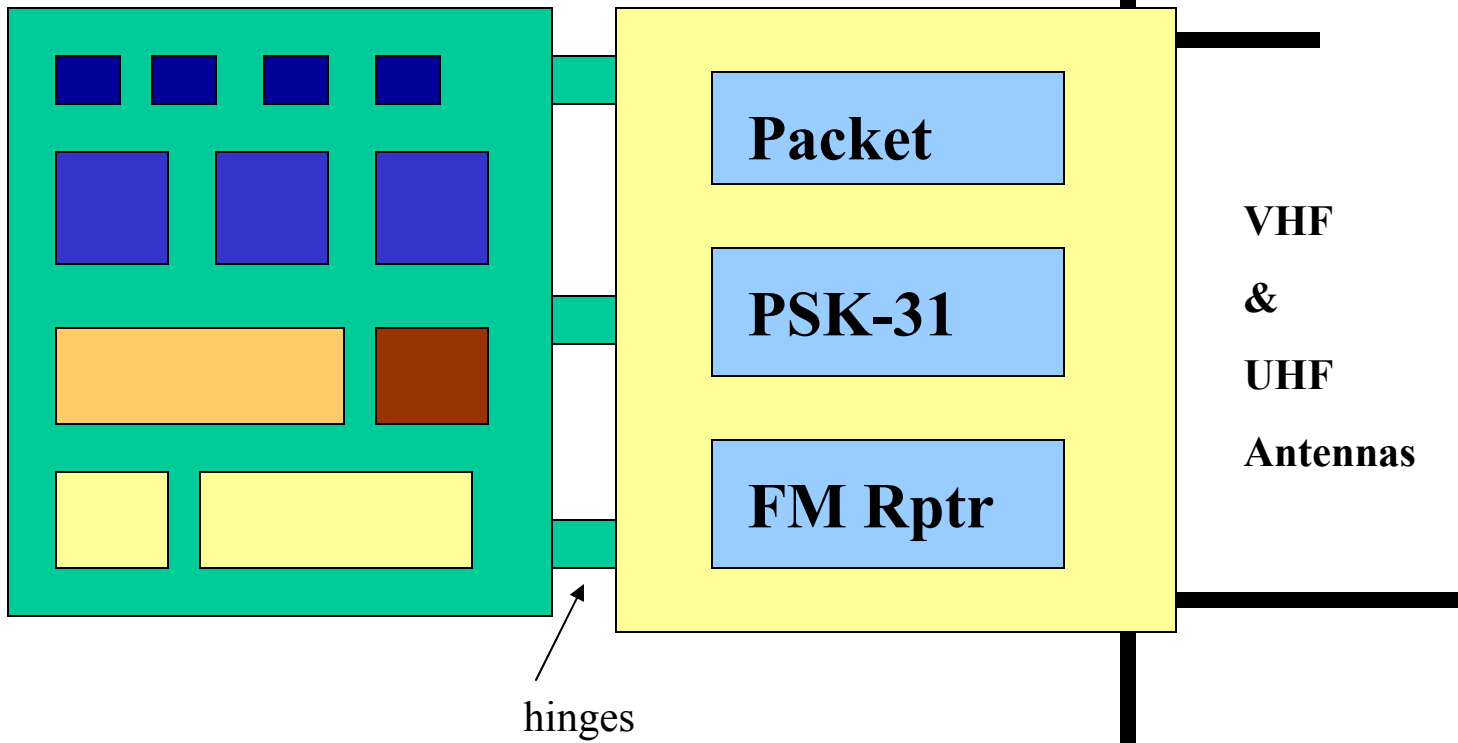
- **Telemetry: 1 Sec burst every 60 secs @ 9600 baud**
- **42 Samples of I-V curve data**



Adding PCsat2 to MISSE5

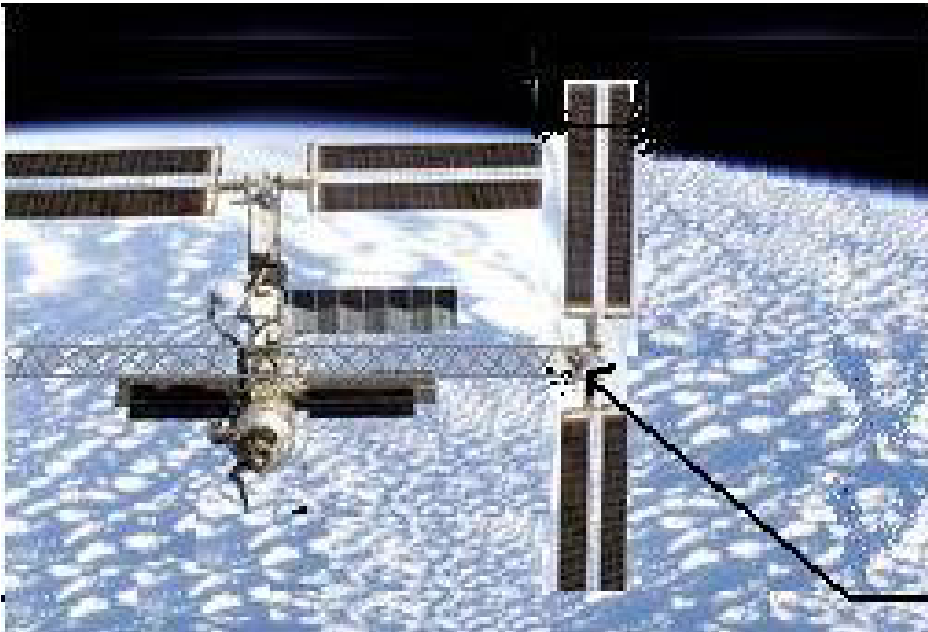
**MISSE5 Solar
Cell Experiment**

**PCsat 2 Comms
Experiment**





External Mounting Location



The preferred location for the PCSat2 external payload is out on the solar array, beyond the alpha joint so that the PCSat2 experiment gets full sun whenever the ISS is in sun.

This drawing shows the ultimate location of the solar arrays at the end of the truss structure by summer 2003.

Thus, our preferred location is about here somewhere...

Because it is a Solar Cell Experiment, the preferred mounting location is beyond the Solar Array Alpha Joint

The solar cells will get full sun when ISS is in sun.



Amateur Radio On ISS Coordination

- **ARISS International Committee** tasked with coordination of all Amateur Radio issues on ISS
- **ARISS Project Selection and Use Committee.**
 - Is this a valid Amateur Satellite Service mission?
 - IARU Frequency Coordination?
 - Technical Team must participate
 - International issues involved.
- **US ARISS Meeting 5-7 December 2002**



The Amateur Satellite Service



“...for the purpose of self-training, intercommunication and technical investigations carried out by persons interested in radio technique solely with a personal aim and without pecuniary interest.”

- **The Purposes** of an amateur satellite should be to:
 - ✓ Provide communication resources for the amateur radio community
 - ✓ Technical investigations consistent with the Radio Regs
 - relevant to the development of "radio technique,"... including...
 - ...studies of radiation effects on various electronic components...
- **Station Control:** licensed amateur radio operators:
 - ✓ acting "solely with a personal aim and without pecuniary interest."
 - ✓ Commonly, the licensee is an unpaid member of the organization ...
 - ✓ or is a volunteer acting in close association with it.
- **Plain Language:** technical descriptions of all emissions, codes, and formats must be made publicly available.
- **Open Access:** for use by amateur radio operators world-wide.... and for reception by students and educators.



PCsat2 in the Amateur Satellite Service



Sponsoring Institution:

US Naval Academy

Operating Organization:

USNA Amateur Radio Club W3ADO

Station Trustee:

Bob Bruninga, WB4APR

Satellite Station Licensee:

Ryan Johnson, K3FOR

- ✓ **Communications** for operators, students and educators worldwide.
- ✓ **Technical investigation** of radiation effects on solar cells
- ✓ **Plain Language** comm links and **Published** telemetry **formats**
- ✓ Worldwide **Open Access** to User communications Transponders
- ✓ **Licensed Control Operators** operating without pecuniary interest (USA, UK, NZ, AUS, S.Africa, S.America and Antarctica)



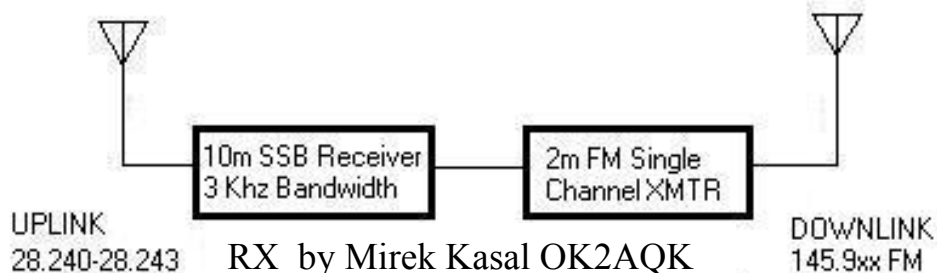
RF Subsystem Requirements

- Dual-Redundant Command and Telemetry System design
- Link budget for simple omni-directional Ground Stations (beams on UHF)
- TX power 2 Watts peak, low duty cycle (average less than 10%)
 - Solar Telemetry < 2,000 bytes per pass (2% duty cycle/Pass at 9600 baud)
 - User Comms (20% duty cycle over USA/Europe at 1200 baud)
- PSK-31 Multi-User Mode (100% duty cycle on case basis)
- Voice repeater mode for ISS Crew (occasional use)
 - (100% duty cycle, on case basis)
- Operate in Sun (Primary to support ARISS School outreach)
- Operate in Eclipse (Secondary as power budget permits)
- Quad Redundant TX Inhibits



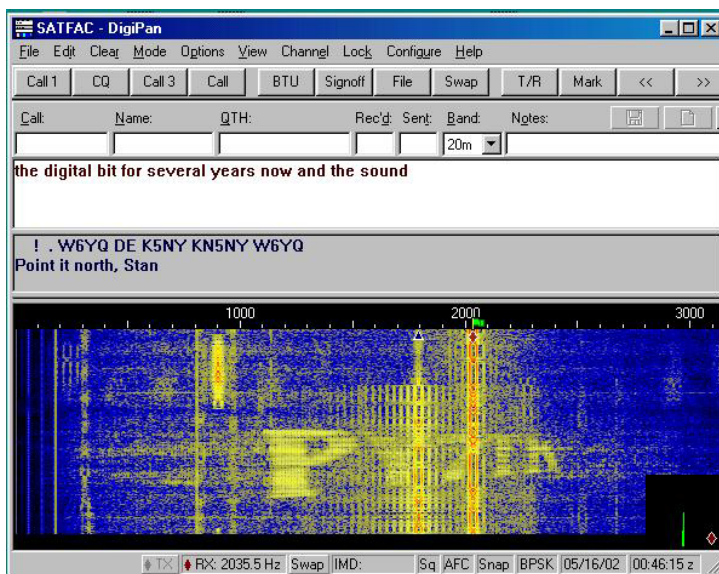
PSK-31 Comms Experiment

PSK-31 SSB=>FM Transponder



NEW Experiment

- Multi-user (20+)
- 3 KHz “wideband”
- Linear-to-FM
- Low Doppler at 29 MHz
- No added linear Doppler on UHF downlink
- Full Duplex
 - Closed Loop AFC
 - Uplinks full period
 - Group QSOs!



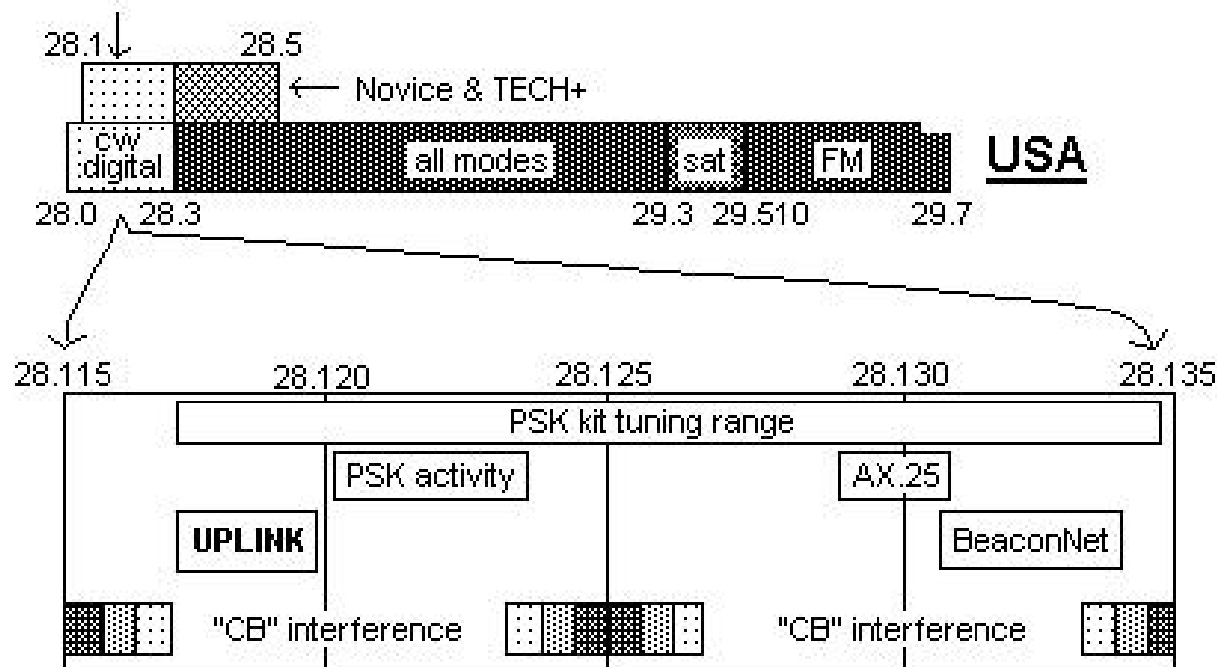


PSK-31 10 Meter Band Satellite Uplink Proposal

ISSUES: 1) ITU rules permit Satellite Operation in the entire 28.0 to 29.7 amateur radio band
2) But IARU national bandplans only mention "downlinks" in 29.3 to 29.51

DISCUSSION: We propose a narrow 3 KHz satellite uplink PSK-31 band at 28.117 to 28.120 MHz

- a) 28.117 prevents wideband-all-mode users from interfering with the uplink
- b) 28.117 permits the Novice/Tech+ operators to use the satellite
- c) 28.117 is adjacent to the existing 28.120 PSK-31 operating band
- d) 28.117 is within the operating range of the off-the-shelf \$89 PSK Transceiver





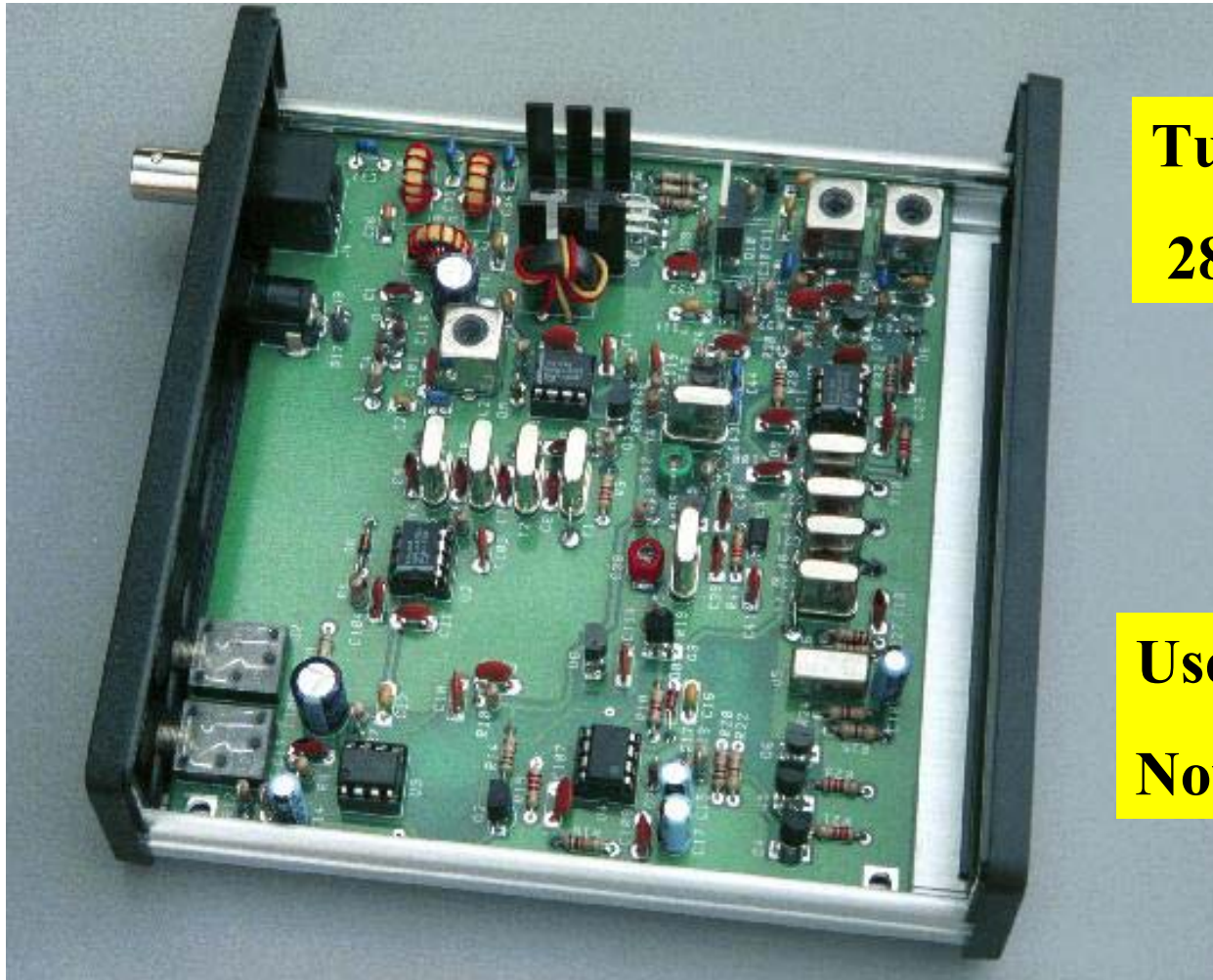
\$85 PSK-31 XCVR Kit

Tunes

28.117 to 28.135

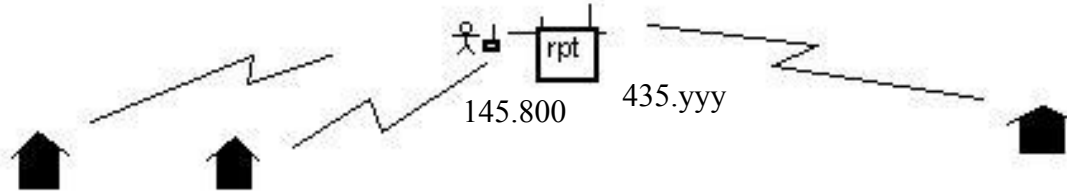
Useable by

Novice and Tech+





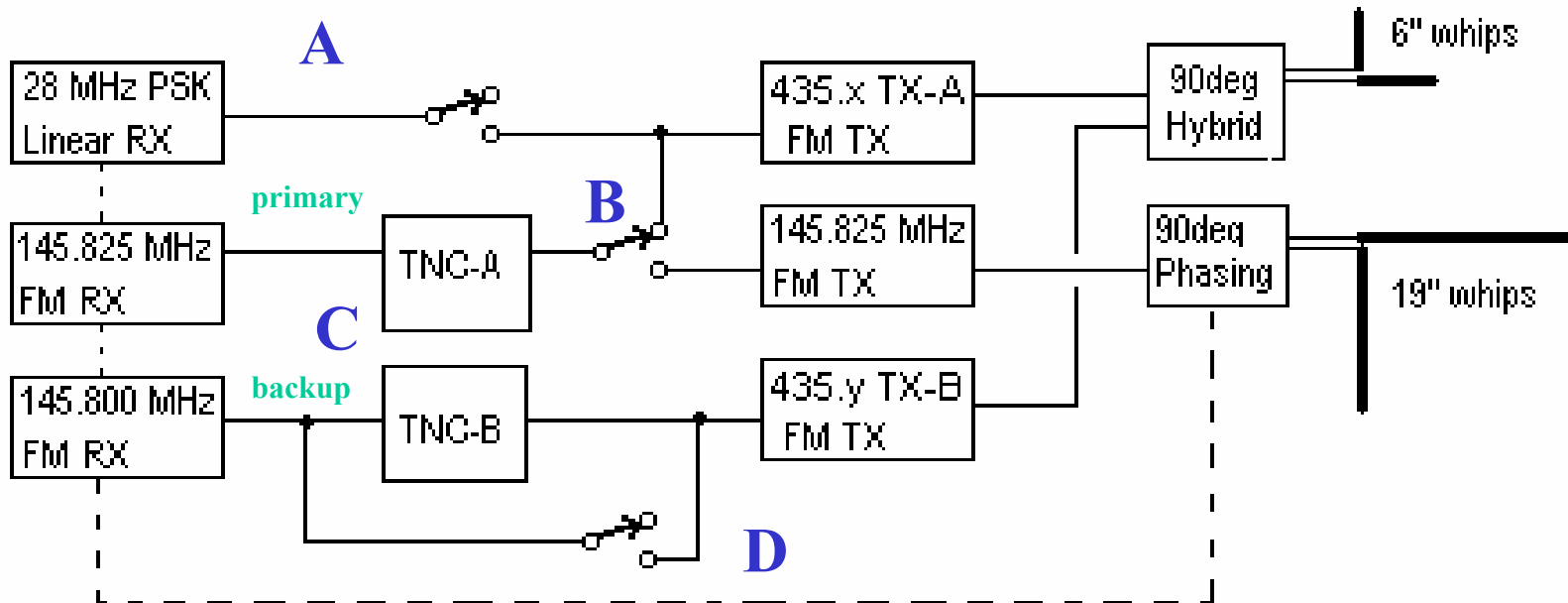
ARISS FM Voice Repeater



- **Full Duplex FM Repeater** (NEW Experiment)
 - Originally proposed by Thomas Kieselbach DL2MDE (sk)
- **School Communications:**
 - Can all hear the uplink and downlink
 - Other schools can hear the questions!
 - Contact EVERY ORBIT (with astronauts on ground)
- **Crew Communications:**
 - Everyone hears the uplink congestion
 - Aural feedback is self-limiting to strongest signal
 - Result is an order of magnitude improvement in comms
 - More Crew involvement



RF Subsystem Block Diagram



-A - Multi-user PSK-31 Data Transponder

-B - Default Downlinks on UHF to avoid EMI to ARISS on 2m band

-C - Dual Redundant Telemetry / Command / Digipeaters

-D - Full duplex FM Voice Transponder (option)



RF System Characteristics

- **TX (downlink) Frequencies**
 - Primary 435.xxx MHz
 - Backup 435.yyy MHz
 - Alternate Experiment 145.825 (always off if Crew is using 2m)
- **RX (uplink) Frequencies**
 - Primary 145.825 MHz (published)
 - Backup 145.800 MHz (not published)
 - PSK31 Multi-user 29.4 MHz
- **EIRP** 2W
- **Modulation Scheme** FM, 3 kHz
- **Data Rate/Bandwidth** 1200 Baud, (15 kHz Bandwidth)
- **Antenna Polarization** Both
- **Command Station**

Primary: Naval Academy, Maryland
 Backup: CA, UK, Hi, Aus, NZ, IT, SA, AN



ARISS RF Compatibility

ARISS Frequencies

145.800 Downlink

144.49 USA Uplinks

145.20 European Uplinks

145.99 Packet Uplinks

437.xxx Future ARISS UHF

PCsat2 Frequencies

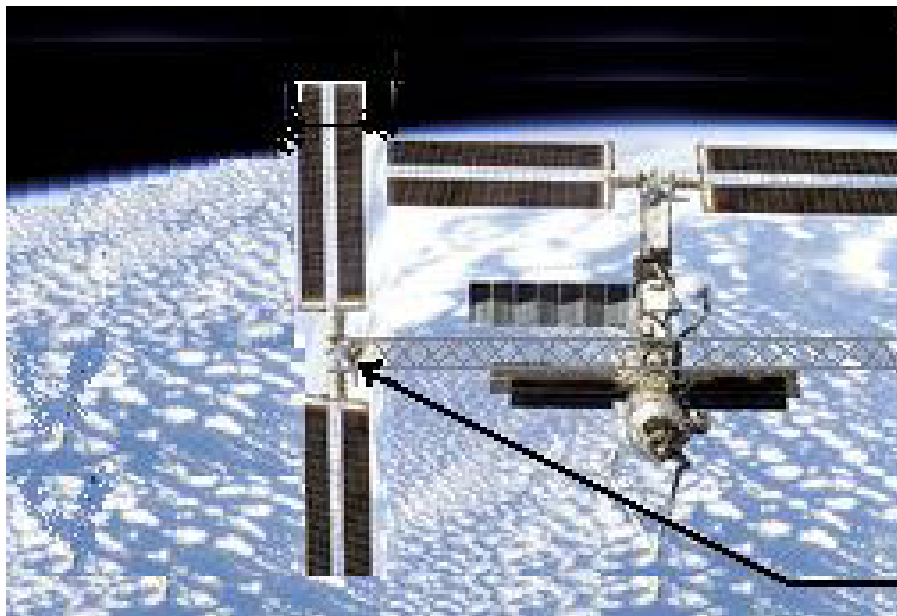
29.4 PSK-31 Uplink

145.825 Packet uplink (Aux Downlink)

145.800 FM Voice Uplink (Backup command)

435.xxx Packet Downlink (and PSK-31)

435.yyy Backup Command Downlink



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This drawing shows the ultimate location of the solar arrays at the end of the truss structure by summer 2003.

Thus, our preferred location is about here somewhere... **120' away**



Mode B DESIRED

MUCH easier for Schools and New users to hear

- ✓ 9 dB stronger signal to OMNI ground station receiver
- ✓ One/third less Coax Loss at ground station
- ✓ No tracking nor Beams required
- ✓ 2m RX more readily available
- ✓ Defends 2m Satellite BAND from interlopers

FUTURE ARISS designs should move towards MODE B

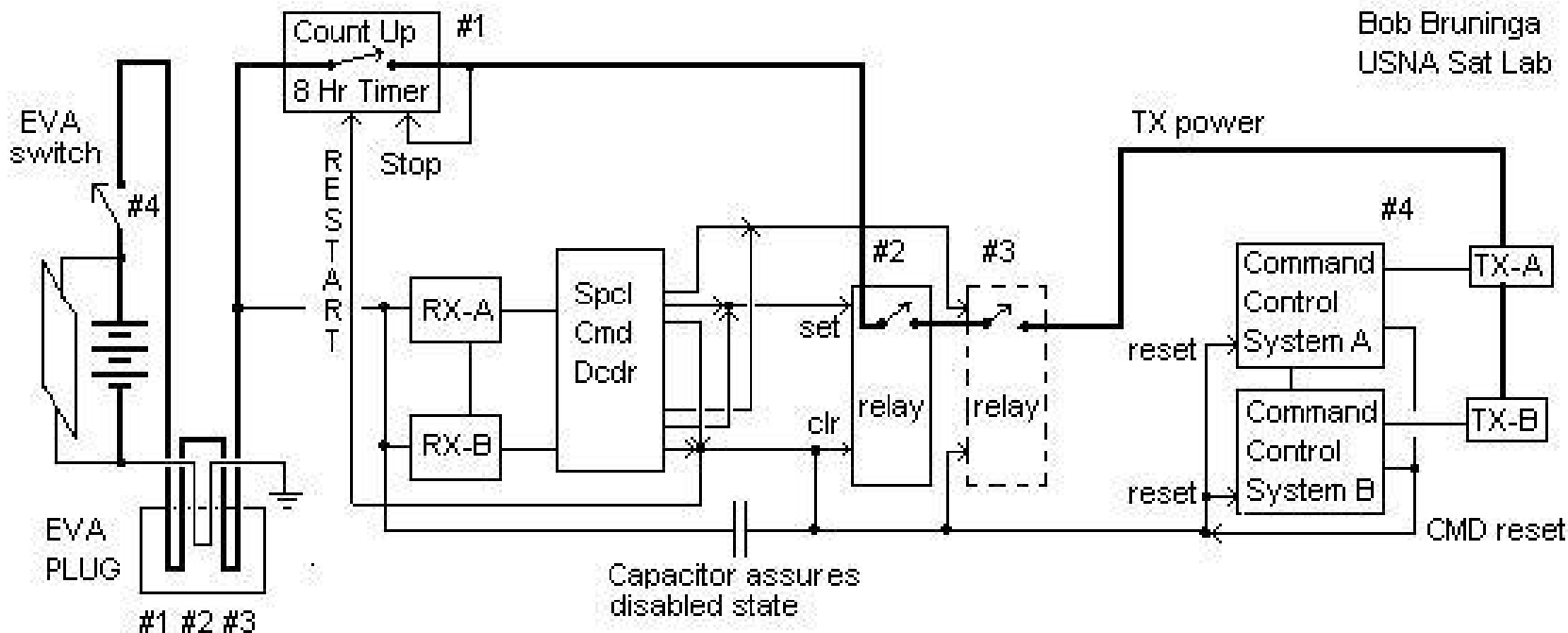
Mode J Required for PCsat2

- **Cannot downlink on 2m due existing ARISS uplinks**
- **PCsat2 Experiment is Temporary (1 year)**



RF TX Inhibit Command System

18 Nov 02
Bob Bruninga
USNA Sat Lab



- 123 - EVA Plug
- 4 - EVA Switch
- 1 - Timer
- 2 - Ground Command enable 2
- 3 - Ground Command enable 3
- 4 - Ground Software Command ON

Special Commands

- * Restart 8 Hr timer (removes all TX power)
- * Set TX-ARM relay 1
- * Set TX-ARM relay 2



RF Subsystem Command Configuration



Dual TNC's (KPC-9612 Plus) provide:

- **9600 bd serial port** communications with Solar Cell Telemetry
- **Ten open-collector Command Switches:**
 - **PSK-31** COMM Transponder **ACTIVATE**
 - **SWITCH Digipeater** to VHF downlink
 - **Voice Repeater ON:** (bypass TNC-B)
 - **RESET** the other TNC
 - **CLEAR** the 72 hour fail safe Timer
 - **POWER CYCLE** the solar power experiment
 - **RESET** the solar power experiment processor
 - Set **TX ARM Relays OFF**
 - **MASTER RESET** and restart 8 hour EVA timer
 - TBD
- **DEFAULT, RESET, LOW POWER and FAILSAFE mode** for all of these outputs are **OFF**.

Transmitter Features

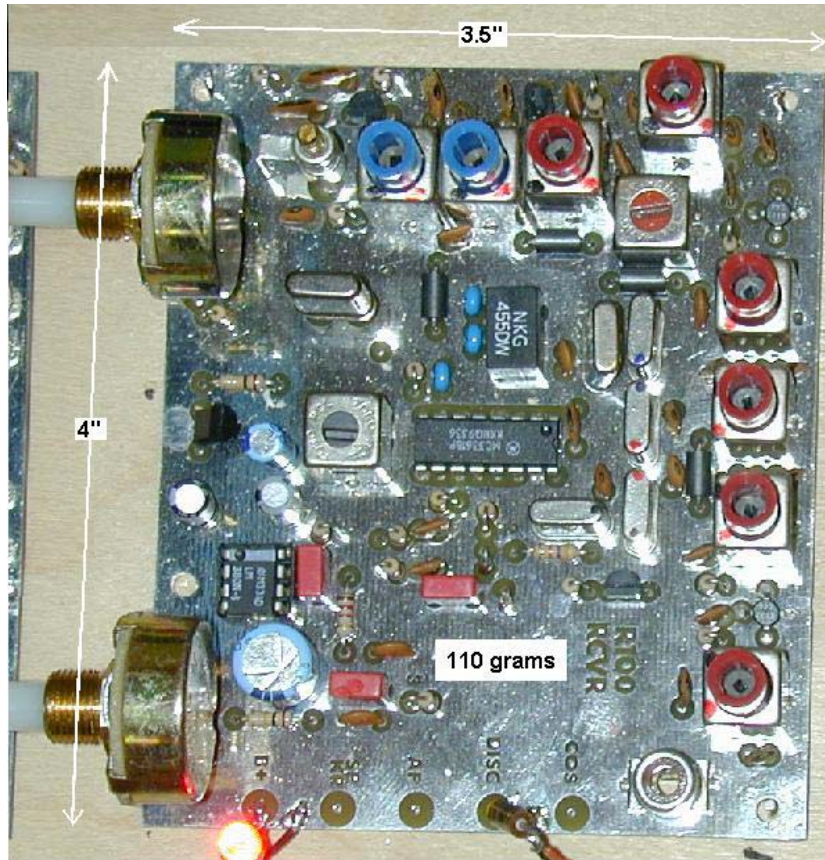


100g

- 2 Watt UHF Transmitter (XTAL controlled) 435.xxx MHz
- 2 Watt VHF Transmitter (XTAL controlled) 145.825 MHz
- FM modulation (1200 bd AFSK, 9600 bd FSK, Voice)



Receiver Features



- **VHF FM RX (xtal controlled)**
 - 145.825 and 145.800 MHz

- **Sensitivity -117 dBm**

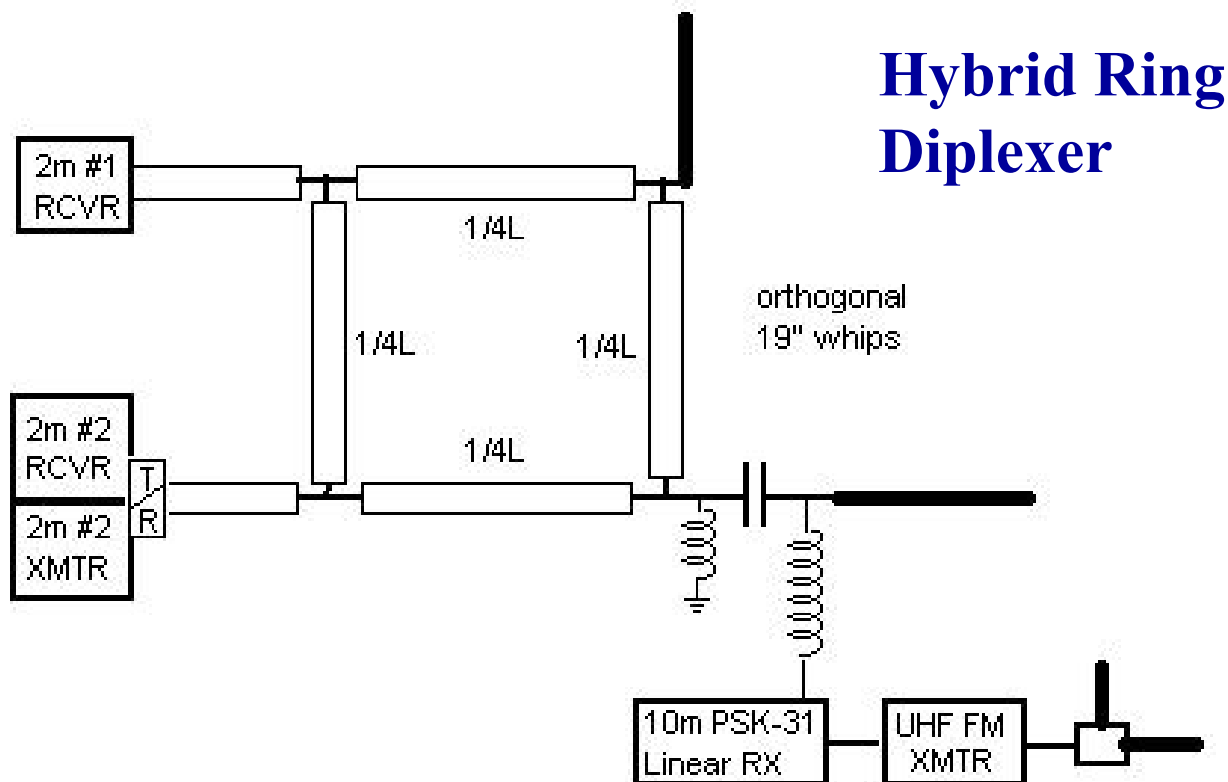
- **Bandwidth 15 KHz**
- **12 Volts (8v regulated)**

- **FM demodulator**
 - -1200 baud AFSK
 - -9600 baud FSK
 - -FM voice

- **Mass 110g**



Antenna Design Concept



The 10m PSK-31 receiver must get its received energy from the two-meter antenna system which consists of two orthogonal 19" whips fed by a hybrid ring. The other two ports of the hybrid ring connect to the two 2m systems.

Probably we will connect the 10m receiver to just one of the whips through a low pass filter as shown here...

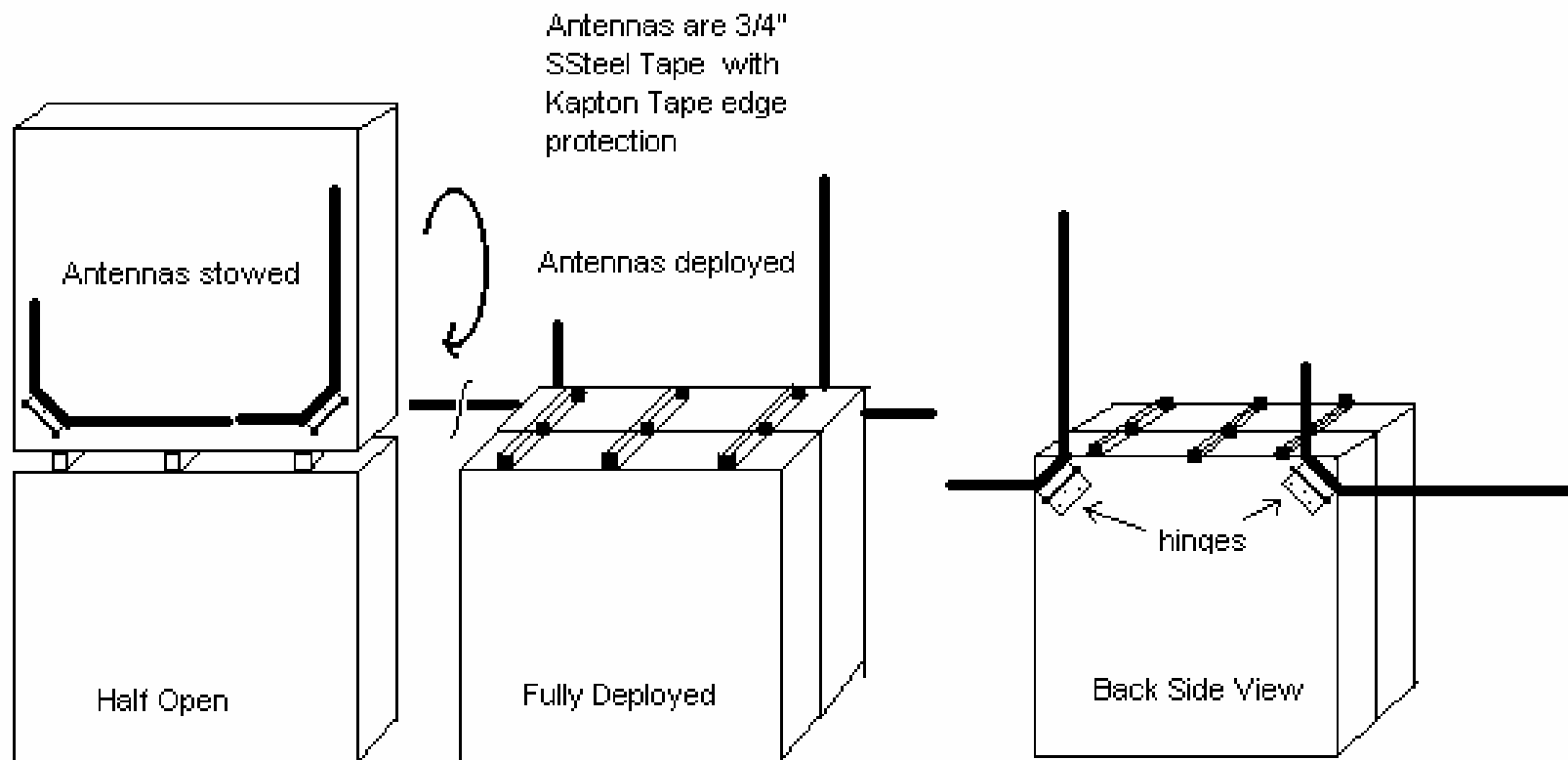


Antenna Deployment/Stowage

PCsat2 Antenna System

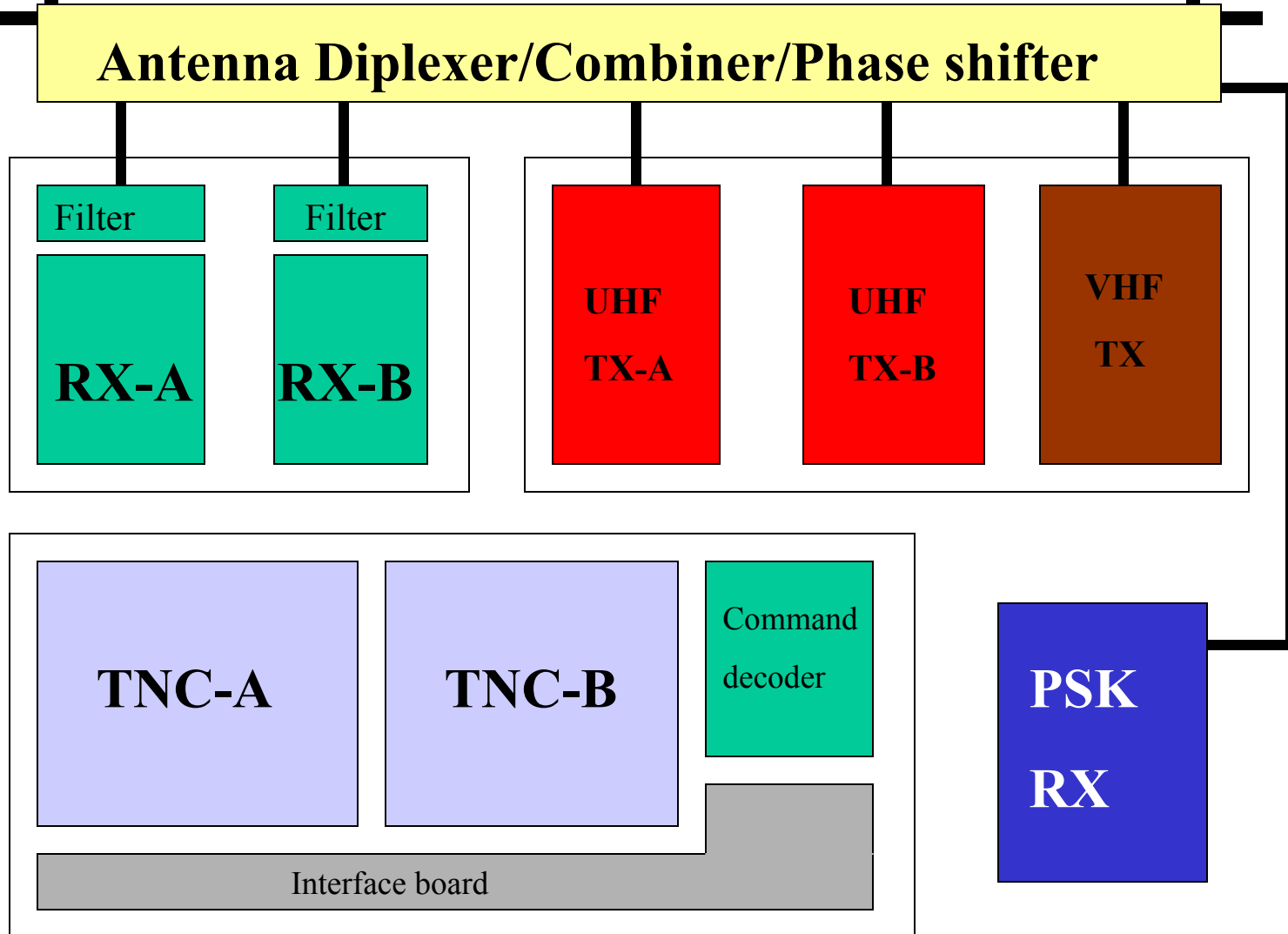
wB4APR

VHF and UHF Antenna systems consist of two sets of orthogonal whips of length 19" and 6.5"





RF Subsystem Packaging Concept





Concept of Operations

- **Cooperate fully with ARISS Operations Planning**
 - Never interfere with School Contacts or Crew Communications
- **Packet Digipeater with UHF downlink usually ON**
 - Won't interfere with normal Voice operations
- **Packet Digipeater on 145.825** on case-by-case basis
- **Downlink Telemetry** once a day over Command Station
- **PSK-31 Experiment** on case basis if **Power** permits
- **FM Full Duplex Voice Repeater for Crew** on case basis



ARISS PMS and UI Digipeating

- **PCsat2 downlink defaults to UHF** to avoid any 2m interference potential
- **If no crew voice ops**, then 145.825 packet downlink is possible to improve ARISS packet throughput
 - **Existing PMS uplink shares PMS and UI users**
 - Throughput is collision-limited (P+U interference)
 - If P users are on 145.99 and U users are on 145.825
 - Fewer Collisions result for both
 - PMS users only see P + %U interference
 - UI Users only see %P + U interference

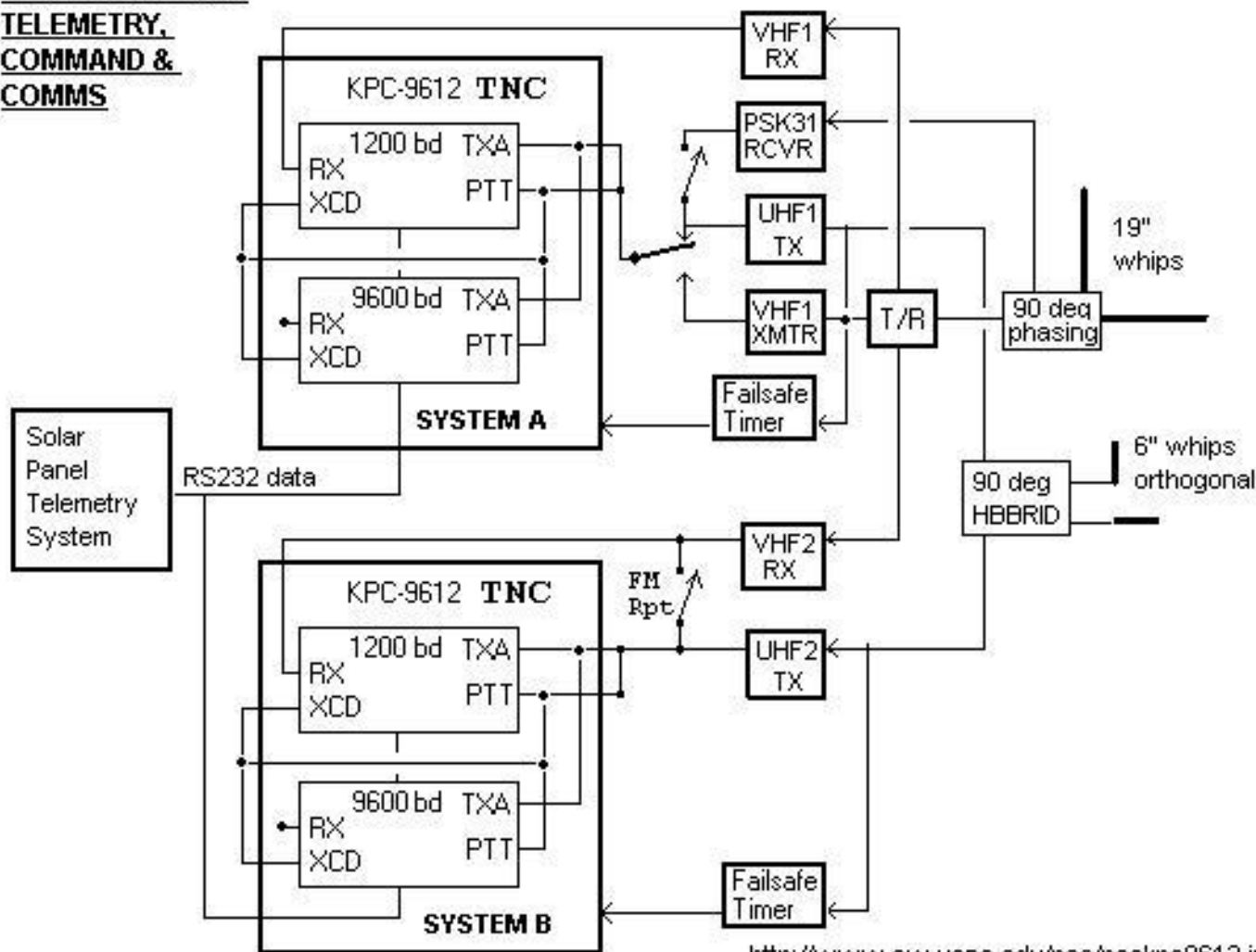
Note: % means success rate



Packet Block Diagram

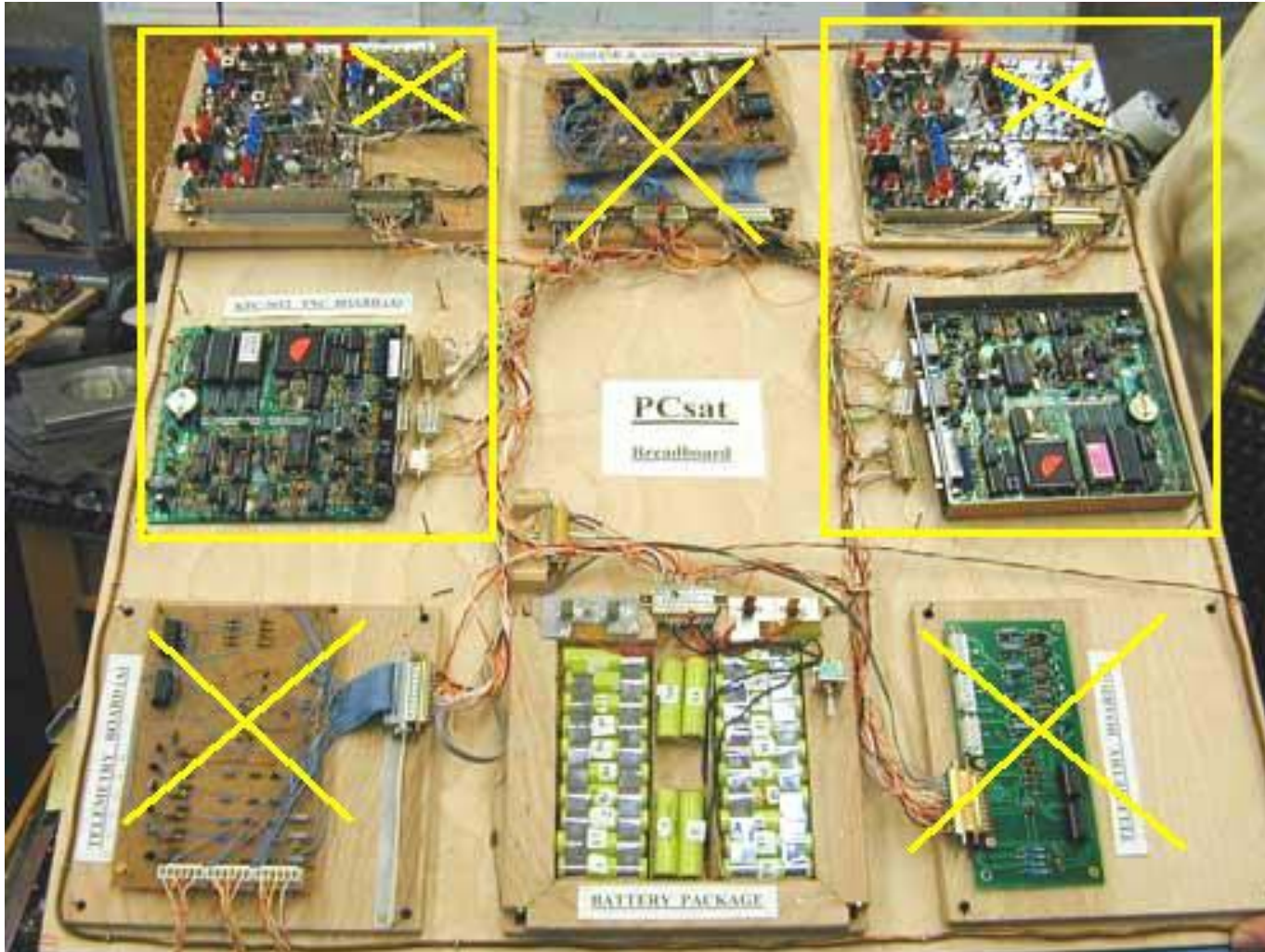
**DUAL REDUNDANT
TELEMETRY,
COMMAND &
COMMS**

18 Nov 2002





PCsat (NO-44) Follow-on Mission



PCsat consisted of dual transponders.

We would recommend dual redundant systems for PECsat as well.

The dual PECsat payloads would consist of the two sections boxed in yellow.

Plus a battery pack.



T&C Telemetry List

- **TNC-A five analog channels**

- Ch1 - 12volt bus
- Ch2 – Battery Current
- Ch3 – Solar Experiment Temperature
- Ch4 – TX-A temperature
- Ch5 – VHF TX Temperature

**1st three channels
are redundant**

- **TNC-B five analog channels**

- Ch1 - 12volt bus
- Ch2 – Battery Current
- Ch3 – Solar Experiment Temperature
- Ch4 – TX-B temperature
- Ch5 – Thermal Plate Temperature



TNC Command List

MYCALL: PCSAT2

MYPBBS: MAIL

MYREMOTE: *SECRET*

UNPROTO: APRS VIA SGATE

UIDIGI: OFF APRSAT, RELAY, WIDE, ARISS

DIGI: OFF

BTEXT: PCsat2 – MISSE5. US Naval Academy

BEACON E: EVRY 3 [NOT INITIAL]

TELEMETRY: 6

BLT 1 e 00:05:59

CONOK: OFF

CMSG: DISC

CTEXT: Mission is UI digipeater only No connections.

PBBS: 100

PTEXT: SYSOP use only. Tnx.

ABEACON: 3 every 5

Callsign2

BBS Store&forward access callsign

Command access callsign

Network routing path

Digipeater Aliases

Allows users to use transponders

3 minute Beacon Text

3 minutes

1 minute Telemetry

6 minute Bulletin

User Connects disabled

User rejected and disconnected

User reject message text

100 K allocated to Store and Forward BBS

BBS User connect response

User store and forward 3 users once every
5 minutes world wide



User's Equipment

- VHF/UHF Transceiver
- Laptop
- Public Domain FREE software



Transceivers



Laptop



Worldwide Internet Linked Ground Stations

All downlinks available live on web via Participating internet linked Ground Stations



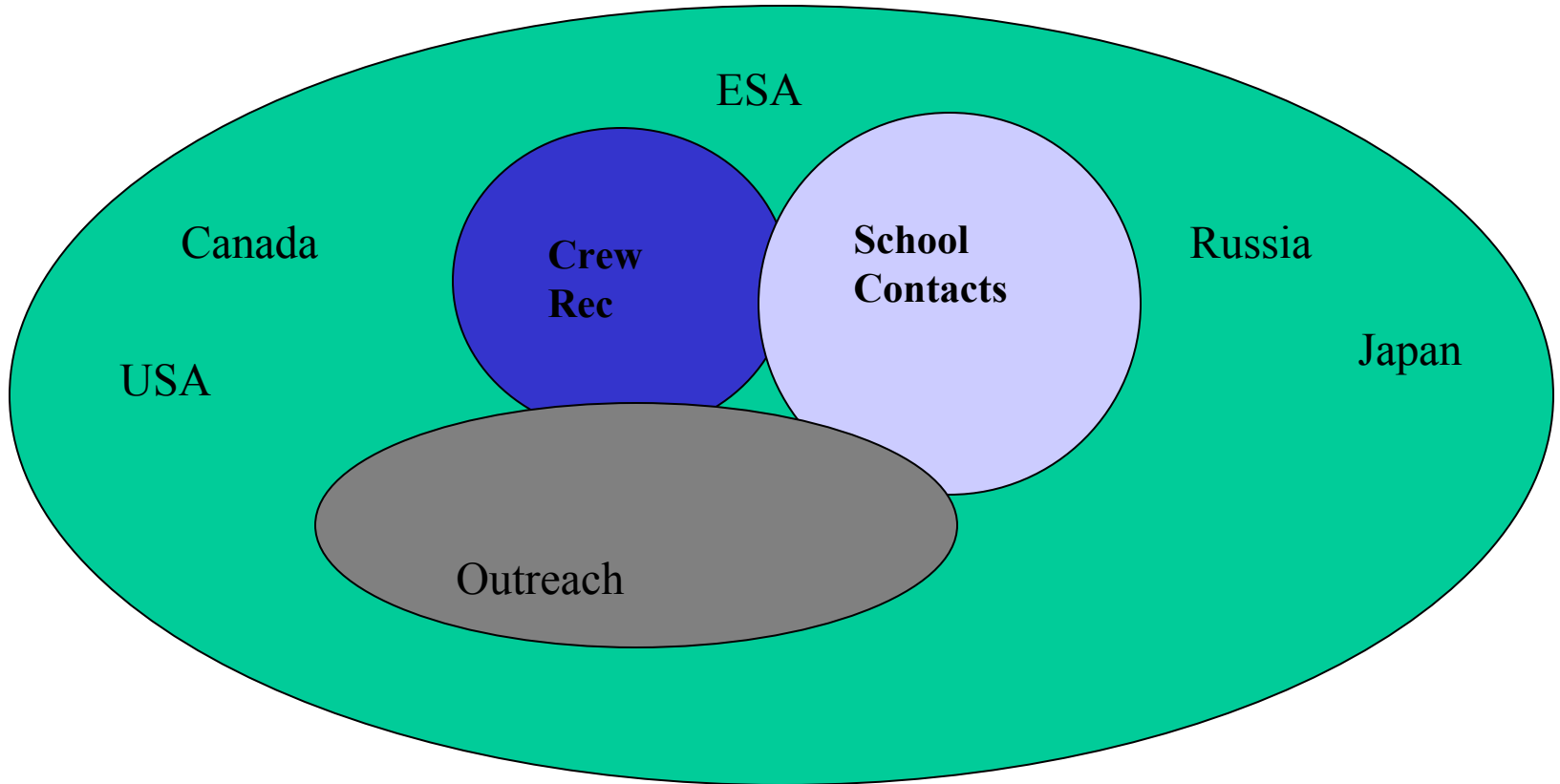
ISS / PCsat Internet Linked
volunteer Groundstations

pcsat.aprs.org
www.ariss.net

TCP IP. WH6SJ
SANA Arctic Station

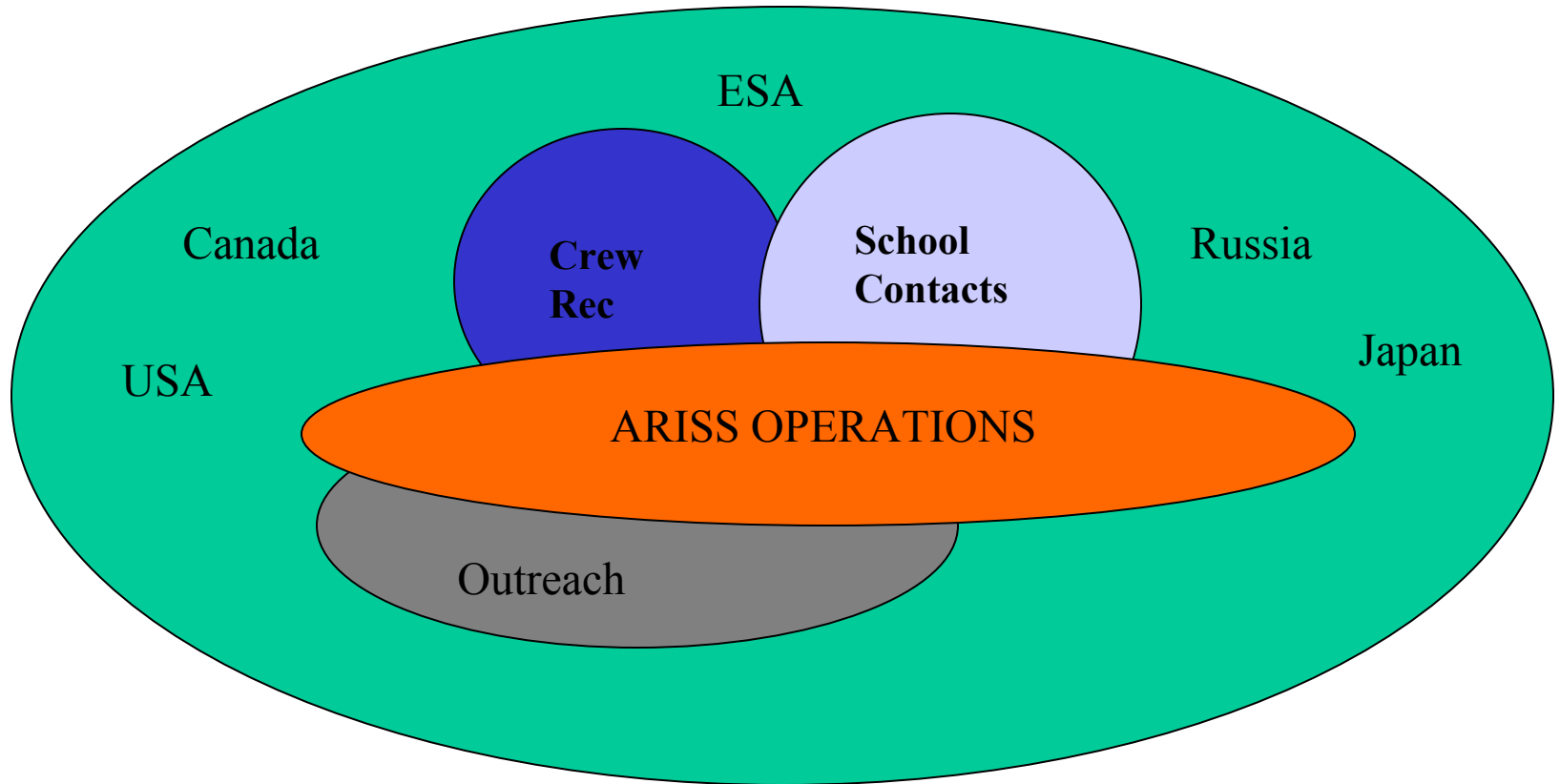


ARISS Mission



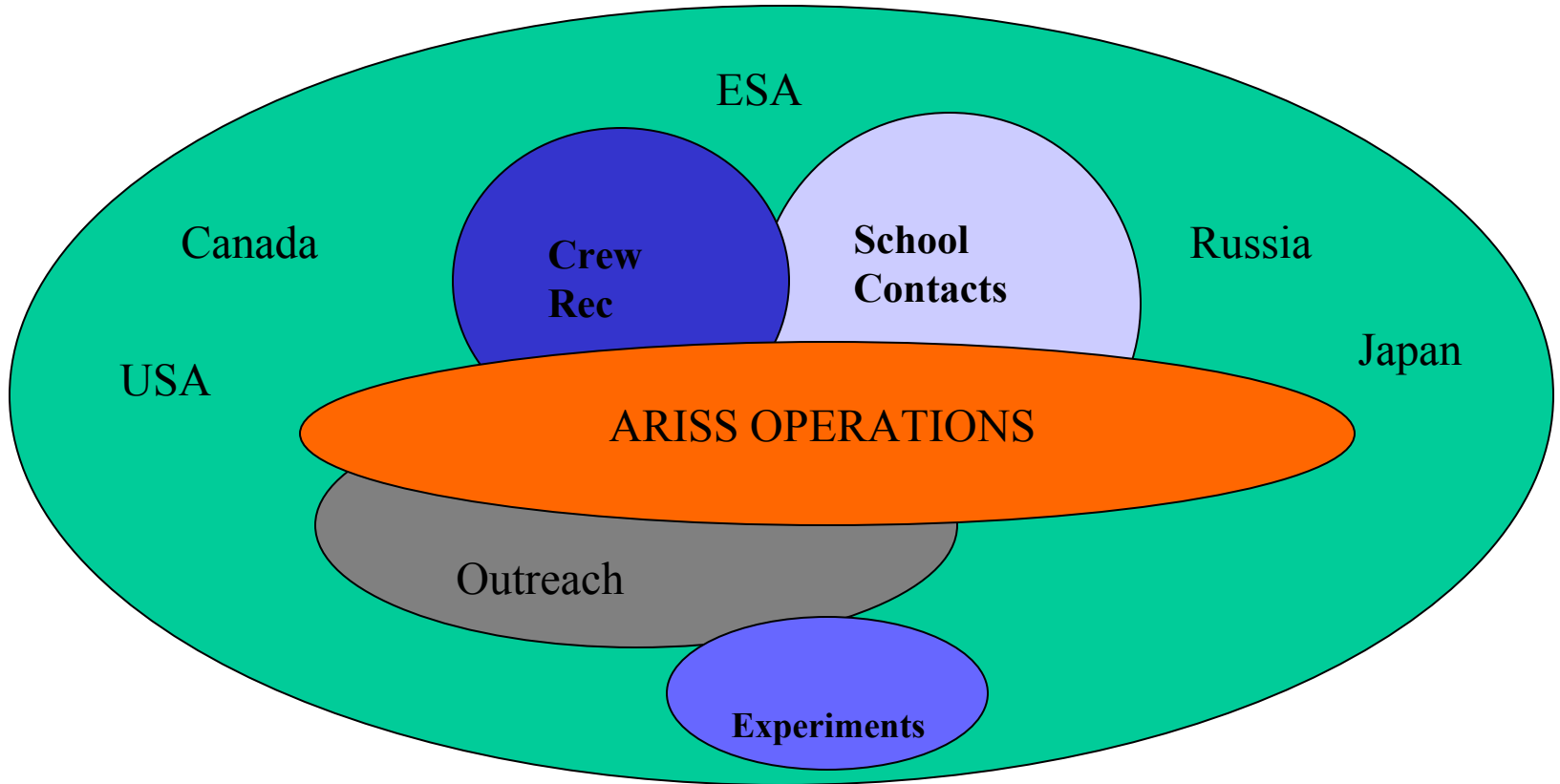


ARISS Mission



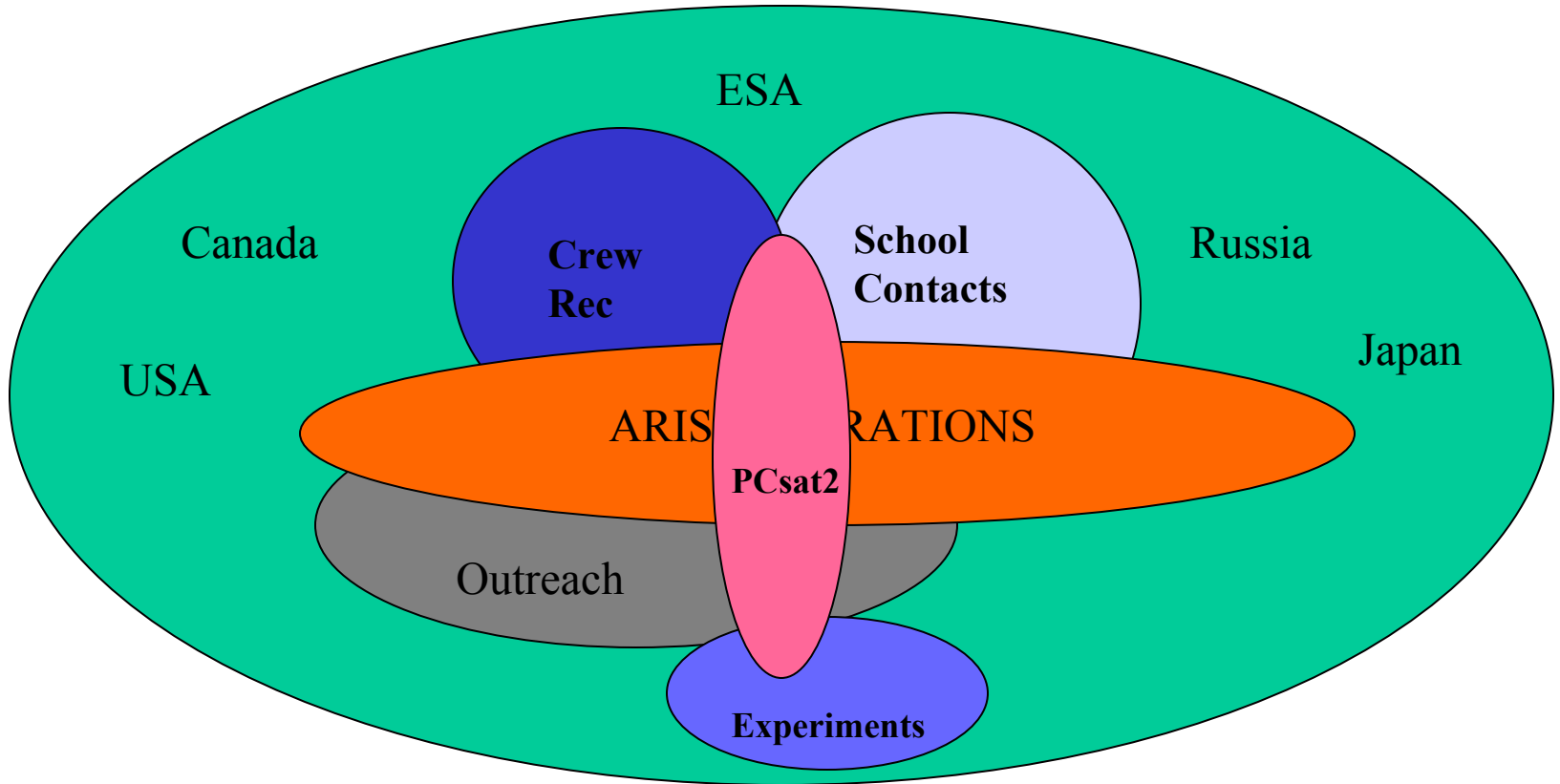


ARISS Mission





ARISS Mission





What does PCsat2 Need?

- **PCsat2 will have:**
 - Fully Funding
 - All Hardware costs
 - All test/integration costs
 - All Launch Installation costs
 - EVA priority
- **PCsat2 NEEDS FROM ARISS & AMSAT:**
 - **ARISS** Approval of OPS Plan
 - PCsat2 will operate in full cooperation with ARISS
 - PCsat2 will never interfere with ARISS School ops
 - PCsat2 will default to OFF and UHF downlinks
 - PCsat2 NEEDS FROM **AMSAT**:
 - Endorsement that PCsat2 is Fully an Amateur Satellite
 - Provides 3 Fully Amateur Communications Transponders
 - Provides Telemetry on Radiation effects on Solar Panels



On Orbit Operations (ARISS)



**Data
&
Voice**



**250
contacts
in 24 hrs**