3. Remote Sensing Bands Used by OES Instruments (1 of 4)

INSTR.	MISSION	CNTRY	1.25	1.4	1.67	2.65	3.2	4.3	4.9	5.3	6.7	7.15	8.6	9.65	10.65	13.6	13.8	15.3	15.4	17.25	18.7	21.3	22.3	23.8	24.1	31.5	35.55	36.5	38	50.3
ALT	TOPEX/ POSEIDON	USA/ FRANCE								X						X														
AMI	ERS-1, -2	ESA								X																				
AMR	EOS-ALTR	USA																			X	X		X				X		
AMSR	ADEOS-2	JAPAN									X				X						X			X				X		X
AMSR-E(J)	EOS-PM	USA									X				X						X			X				X		
AMSU	EOS-PM	USA																					X	X		X				X
AMSU-A	NOAA K+ METOP1	USA ESA																						X		X				X
AMSU-B	NOAA-K+	USA																												
ASAR	ENVISAT	ESA								X																				
ASCAT	METOP	ESA								X																				
ATSR, -2	ERS-1, -2	ESA																						X				X		
CLOUD RADAR	FUTURE	ESA																												
DELTA-2	OKEAN	CSR										X				?							X					X		
Radiometer	HYDROSAT	USA		X																										
IKAR	PRIRODA	CSR								X						X							X					X		
MASTER	FUTURE	ESA																												
MHS	EOS-PM NOAA-N METOP	USA USA ESA																												
MIMR	METOP	ESA									X				X						X			X				X		
MIRAS	MIRAS	ESA		X																										
MIVZA	METEOR	CSR																				?						X		
MLS	EOS-CHEM	USA																												
MLS	UARS	USA																												
MSR	MOS-1B	JAPAN																						X		X				
MSU	NOAA-9-14	USA																												X
MTZA	METEOR	CSR																				?						X		X
MWR	ENVISAT	ESA																						X				X		

3. Remote Sensing Bands Used by OES Instruments (2 of 4)

INSTR.	MISSION	CNTRY	50.3	55	64.5	65.5	78.5	89.	94	101	110	121	150.5	157	166	175.5	183	201	224	236	251	276	301	325	346	364	380	>400
ALT	TOPEX/ POSEIDON	USA/ FRANCE																										
AMI	ERS-1, -2	ESA																										
AMR	EOS-ALTR	USA																										
AMSR	ADEOS-2	JAPAN	X	X				X																				
AMSR-E(J)	EOS-PM	USA						X																				
AMSU	EOS-PM	USA	X	12				2									4											
AMSU-A	NOAA K+, METOP1	USA ESA	X	X				X																				
AMSU-B	NOAA-K+	USA						X						X			3											
ASAR	ENVISAT	ESA																										
ASCAT	METOP	ESA																										
ATSR, -2	ERS-1, -2	ESA																										
CLOUD RADAR	ESA FUT.	ESA					?		X																			
DELTA-2	OKEAN	CSR																										
Radiometer	HYDROSAT	USA																										
IKAR	PRIRODA	CSR								X																		
MASTER	FUTURE	ESA																X					X	X	X			
MHS	EOS-PM NOAA-N METOP	USA USA ESA						X					X		X		3											
MIMR	METOP	ESA						X																				
MIRAS	MIRAS	ESA																										
MIVZA	METEOR	CSR						5																				
MLS	EOS-CHEM	USA																	X				X					2
MLS	UARS	USA			X												X	X										
MSR	MOS-1B	JAPAN																										
MSU	NOAA-9-14	USA	X	3																								
MTZA	METEOR	CSR	X	6				?																				
MWR	ENVISAT	ESA																										

3. Remote Sensing Bands Used by OES Instruments (3 of 4)

INSTR.	MISSION	CNTRY	1.25	1.4	1.67	2.65	3.2	4.3	4.9	5.3	6.7	7.15	8.6	9.65	10.65	13.6	13.8	15.3	15.4	17.25	18.7	21.3	22.3	23.8	24.1	31.5	35.55	36.5	38	50.3
MZOAS	METEOR	CSR									?				?						?		?					?		
NSCAT(US)	ADEOS	JAPAN															X													
PR	TRMM	JAPAN															2													
QuikSCAT	QuikSCAT	USA														X														
R-225	OKEAN-O	CSR														?														
R-400	PRIRODA	CSR										?																		
R-600	OKEAN-O	CSR							X																					
RA	ERS-1,-2	ESA															X													
RA-2	ENVISAT	ESA					X										X													
RADIOMTR	ODIN	SWEDEN																												
RLSBO	OKEAN-O, SICH-1	CSR												X																
RM-0.8	SICH	CSR																											X	
SAR	RADARSAT	CANADA								X																				
SAR	JERS-1	JAPAN	X																											
SAR	SICH	CSR	X																											
SAR-10	ALMAZ	CSR					X																							
SAR-3	ALMAZ	CSR											X																	
SAR-70	ALMAZX	CSR																												
SIRC/XSAR	Shuttle	USA	X							X				X																
SMR	SICH	CSR									?				?						?		?					?		
SEAWINDS (USA)	ADEOS-2	JAPAN														X														
SLR-3	ALMAZX	CSR											X																	
SOPRANO	FUTURE	ESA																												
SSALT	TPX/POS, JASON	USA, FRANCE								X						X														
TMI (USA)	TRMM	JAPAN													X							X						X		
TMR	TPX/POS, JASON	USA, FRANCE																			X	X						X		
TRVRS SAR	PRIRODA	CSR	X				X																							
VSAR	ALOS	JAPAN	X																											

3. Remote Sensing Bands Used by OES Instruments (4 of 4)

INSTR.	MISSION	CNTRY	50.3	55	64.5	65.5	78.5	89	94	101	110	121	150.5	157	166	175.5	183	201	224	236	251	276	301	325	346	364	380	>4000
MZOAS	METEOR	CSR						10																				
NSCAT(US)	ADEOS	JAPAN																										
PR	TRMM	JAPAN																										
QuikSCAT	QuikSCAT	USA																										
R-225	OKEAN-O	CSR																										
R-400	PRIRODA	CSR																										
R-600	OKEAN-O	CSR																										
RA	ERS-1,-2	ESA																										
RA-2	ENVISAT	ESA																										
RADIOMTR	ODIN	SWEDEN										X																2
RLSBO	OKEAN-O, SICH-1	CSR																										
RM-0.8	SICH	CSR																										
SAR	RADARSAT	CANADA																										
SAR	JERS-1	JAPAN																										
SAR	SICH	CSR																										
SAR-10	ALMAZ	CSR																										
SAR-3	ALMAZ	CSR																										
SAR-70	ALMAZX	CSR																										
SIRC/XSAR	Shuttle	USA																										
SMR	SICH	CSR						X																				
SEAWINDS (USA)	ADEOS-2	JAPAN																										
SLR-3	ALMAZX	CSR																										
SOPRANO	FUTURE	ESA																										4
SSALT	TPX/POS, JASON	USA/FR USA/FR																										
TMI (USA)	TRMM	JAPAN						X																				
TMR	TPX/POS, JASON	USA/FR USA/FR																										
TRVRS SAR	PRIRODA	CSR																										
VSAR	ALOS	JAPAN																										

4. Vulnerabilities (January, 1998)

Remote Sensing Bands:

One remote sensing band is being challenged by possibly incompatible users:

- Passive band at 18.6 - 18.8 GHz;

- U.S. National WP-7C providing technical bases for our defense/protection.

The allocation of remote sensing bands above 71 GHz is a topic for WRC-99 discussion and revision; technical studies are underway.

Communications/Navigation Bands:

The EESS-desired communications bands of 8025-8400 MHz and 25.5-27.0 GHz secured primary protection worldwide at WRC-97.

- U.S. National WP-7C provided technical bases for upgrading the allocations.

A proposal at WRC-97challenged the protection given to one of the Global Positioning System frequencies. This protection must be defended at WRC-99.

Licensing:

NASA's EOS AM-1 spacecraft has proceeded through the Stage 4 (Operational) review by the Spectrum Planning Subcommittee of the NTIA. But, operating limits may still be imposed by the NTIA's Frequency Assignment Subcommittee:

- DoD has uplinks in our 8025-8400 MHz downlink band and may insist on coordinating with all ground stations, including Direct Broadcast users.

- The Deep Space Network operates in an adjacent band and is extremely sensitive to out-of-band emissions. The EOS AM-1 spacecraft is noisy in this regard and will require coordination of operations to avoid problems. Radio astronomers may also be affected.

Careful design of subsequent EOS spacecraft, employing available technology, should remove the need for operational coordination, which tends to be expensive.

NOTE: NTIA has a 4-stage review process that begins with the concept of the system (phase A) - see Appendix D.

4. Vulnerabilities (September, 1996)

Operational Concerns:

Potential interference caused by EOS AM-1 Direct Broadcast may require:

- coordination with the Deep Space Network (internal to NASA), and
- coordination with the radio astronomers (external to NASA, but if DSN limits are met, radio astronomy is OK).

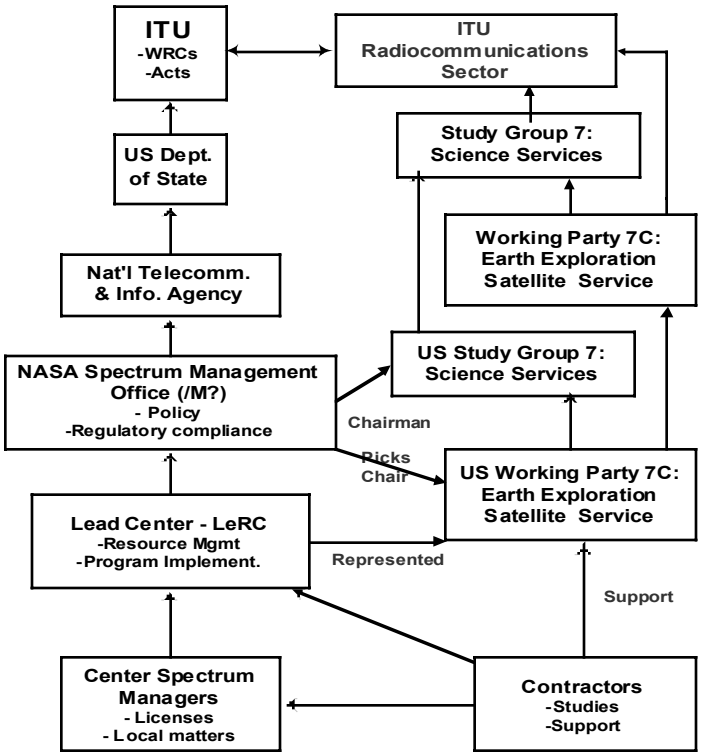
Potential interference caused by EOS Direct Broadcast and/or direct downlinking of wideband, high-rate data may require:

- Coordination with other EESS users of the band, including the new commercial sector. However the scale of this contention problem is TBD.

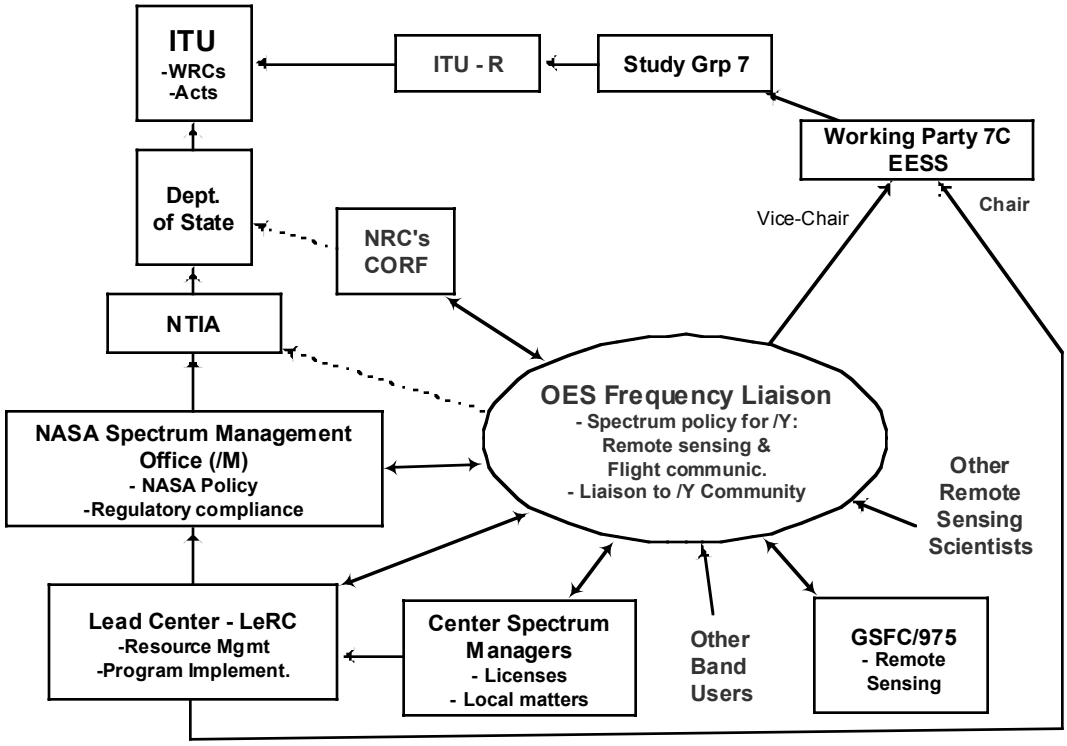
---

5. Mechanism for Change

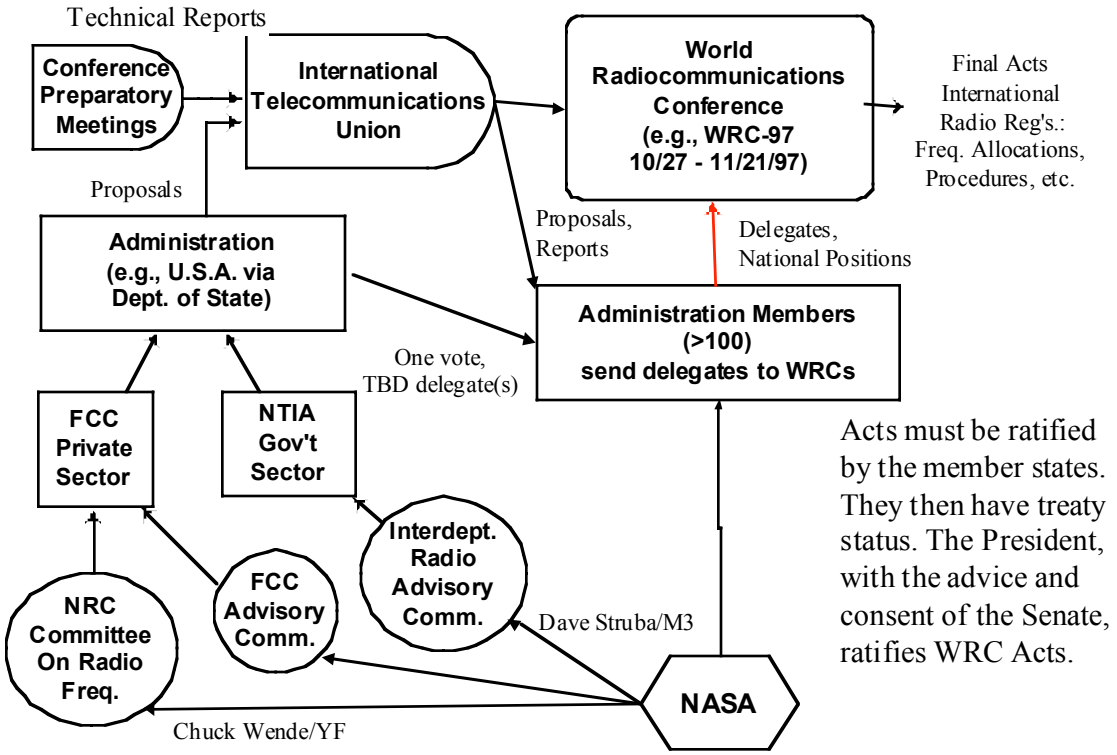
The mechanisms for changing the Radio Regulations are illustrated in the following set of flow charts and organization charts, culminating in a table that presents the schedule of the events. Figure 5a and 5b show the spectrum management structure from a NASA perspective (5a) and how OES (Code Y) interacts with the system (5b). Figures 5c and 5d show the political flow (how proposed changes are processed) and the technical flow (how the technical backup required to demonstrate the validity of the proposed changes is entered). Figures 5e through 5h simply illustrate the structure of the ITU, per se. Finally, the schedule that drives all of the above is given as figure 5I. In addition, the NASA-ESA Coordinating Meetings and meetings of the Space Frequency Coordinating Group are also shown. These groups, while informal and not a part of the ITU, serve as a means for the space-faring nations to discuss common problems and to align their activities for the common good.



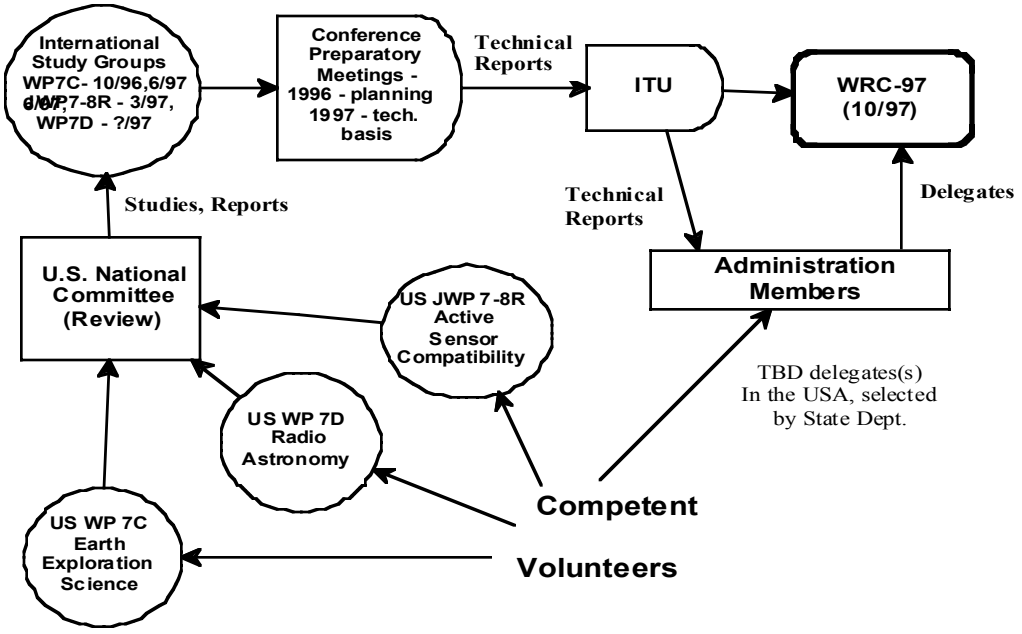
5a. NASA Line Management of Spectrum Matters



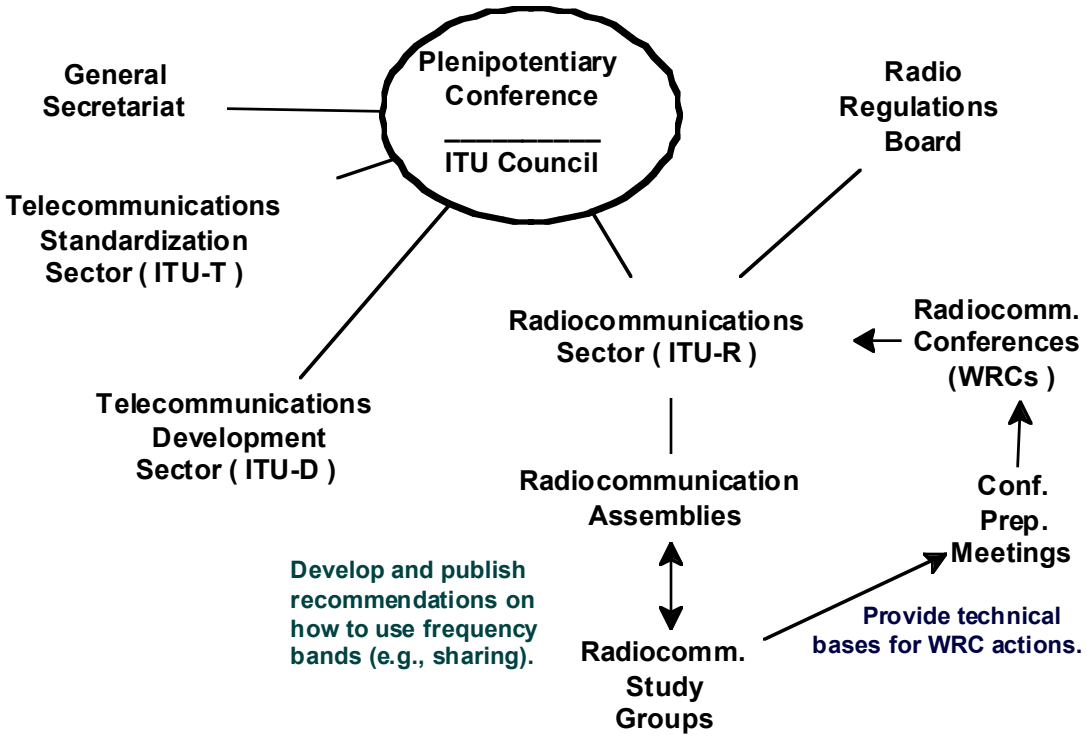
5b. NASA OES Spectrum Management Interfaces



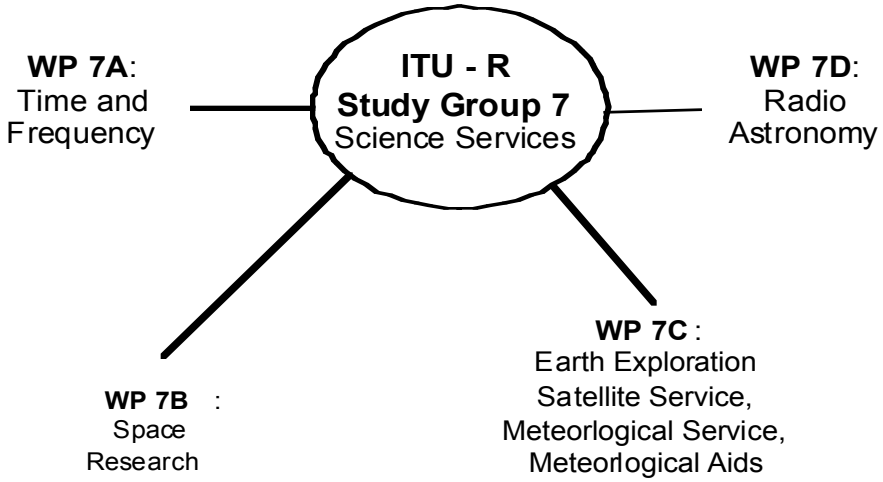
5c. Political Flow into World Radiocommunication Conferences



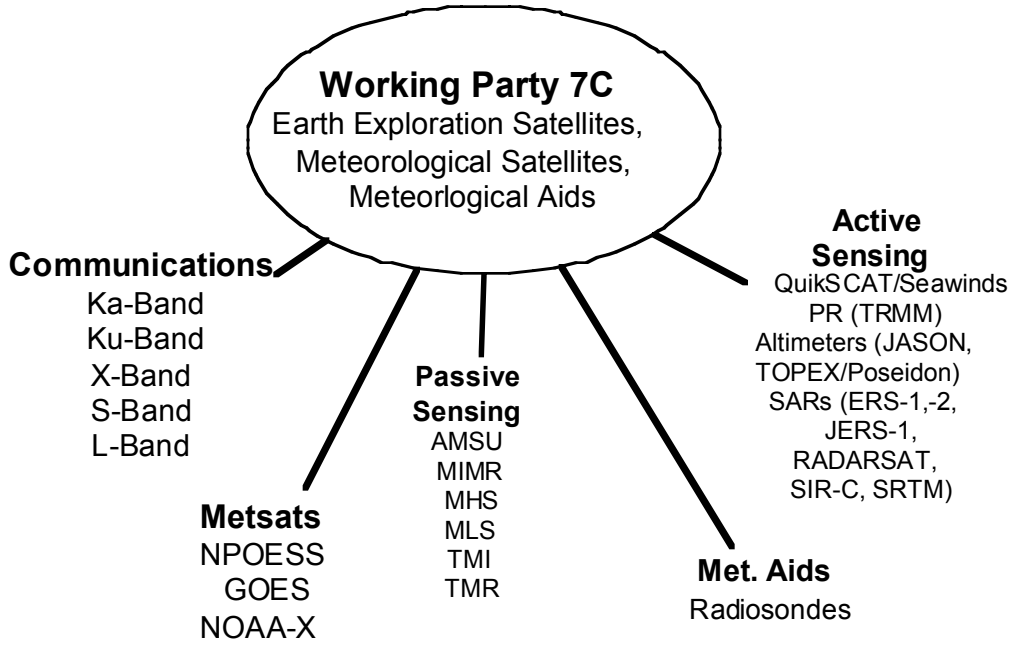
5d. Technical Flow into World Radiocommunications Conference - 97.



5e. Organization Chart of the ITU



5f. ITU-R Study Group 7 Components, U.S. Structure



5g. ITU-R Working Party 7C Components

	NASA-ESA	Int'l SFCG	US WP 7C	US SG-7	US Dept of State	Int'l WP 7C	Int'l SG-7	Int'l CPM	Int'l WRC
Oct-97									X
Nov-97				USA					X
Dec-97			X		Implement				
Jan-98			X		Results				
Feb-98			X					Plan '99	
Mar-98			X						
Apr-98			X	DC?					
May-98			X						
Jun-98	USA		X			X			
Jul-98			X						
Aug-98			X		Rev. Docs				
Sep-98		TBD	X						
Oct-98						X	X		
Nov-98			X	USA				Draft Text	
Dec-98			X		CPM				
Jan-99			X		prep.				
Feb-99			X						
Mar-99			X					Tech.	
Apr-99			X	DC?	Pick			Bases	
May-99			X		Delegates				
Jun-99	Paris?		X			x?	?		
Jul-99			X						
Aug-99			X						
Sep-99		TBD	X				?		
Oct-99									X

5i. ITU and Ancillary Meeting Schedule

6. Parallel Efforts and Support

Workshops sponsored by NASA, others, e.g.:

- X-band (1994 at GSFC, 1995 at Vandenberg AFB).
- Microwave Sensing (11/96 in Boston, with URSI, NOAA).
- S-Band Workshop (July, 1997 at GSFC)
- Ka-Band Commercialization Workshop (March, 1998 at GSFC).

NRC Committee on Radio Frequencies (CORF):

- Mostly radio astronomers, some remote sensing.
- Comments on ITU white papers.
- Responds to FCC notices, Inquiry on Rulemaking.

Industry Advisory Committees (FCC):

- NASA can have representatives.

NASA-ESA Coordinating Meetings:

- Once/year (Japanese observer last time).

Space Frequency Coordinating Group (SFCG):

- Most international space agencies.
- Members influence their administration's proposals.
- Meets in Moscow before SG 7 meets in Geneva this year.
- Meets in Houston next year.

Committee on Telecommunications for the Organization of the American States (CITEL):

- US delegation from government agencies (NTIA, FCC, DoS) and the private sector.

7. Open Issues of the Day

WRC - 00 Issues of Interest to OES *UNDER REVISION*

Originally scheduled for the fall of 1999, this WRC has been postponed to the Spring of 2000 and moved to Istanbul, Turkey.

ACTIVE REMOTE SENSING BANDS:

- 420 - 470 MHz: Providing a 3.5 MHz band somewhere between 420 - 470 MHz for future active, space-based sensors to study biomass, geology, and mudflows underlying vegetation. No such allocation presently exists. 3.5 MHz is inadequate; 10 MHz is needed. JWP 7-8R concluded compatibility between SARs and amateur radio services not established for the preferred 430-440 MHz band. The state of California is interested in such a system. Time was deferred to WRC-99 (now WRC-00), providing that time and money were available to support it. Time and money were declared not available, and it has been dropped from the WRC-00 agenda.

PASSIVE REMOTE SENSING BANDS:

The following passive bands remain a concern for WRC-99 or later WRC's.

- 4.2 - 4.4 GHz: Secondary allocation, best used to observe sea surface temperature. No known instruments, less interference than 6.425-7.075 GHz. The Japanese are interested in elevating this band to worldwide primary status.

- 4.95 - 4.99 GHz: Secondary allocation, best used to observe estuarine temperature. No known instruments, inadequate bandwidth.

- 6.425 - 7.075 GHz: Minimal protection via footnote (not even secondary allocation), observations over oceans, but still much interference. Instruments affected: AMSR (ADEOS-2, Japan), AMSR-E (EOS-PM, USA), MIMR (METOP, ESA), MZOAS (METEOR, CSR), and SMR (SICH, CSR).

- 18.6 - 18.8 GHz: Primary in Region 2 (the Americas) <u>only</u>, secondary elsewhere. Threatened by fixed (point-to-point) and fixed-satellite (point-to-point via satellite) services. Used to observe observing rain, sea state, ocean ice, and water vapor. Instruments affected: AMR (JASON, France/USA), AMSR (ADEOS-2, Japan), AMSR-E (EOS-PM, USA), MIMR (METOP, ESA), MZOAS (METEOR, CSR), SMR (SICH, CSR), and TMR (TOPEX/POSEIDON, France/USA; JASON, France/USA). Although proposed for primary allocation at WRC-97, the proposal went nowhere and action was set aside until WRC-99 to

enable further study.

- 21.2 - 21.4 GHz: Primary allocation, best used for water vapor/liquid observations. Instruments affected: AMR (JASON, France/USA), MIVZA (METEOR, CSR), MTZA (METEOR, CSR), TMI (TRMM, Japan/USA), and TMR (TOPEX/POSEIDON, France/USA; JASON, France/USA).

- 22.21 - 22.5 GHz: Primary allocation, best used for water vapor/liquid observations. Instruments affected: AMSU (EOS-PM, USA), DELTA-2 (OKEAN, CSR), IKAR (PRIRODA, CSR), MZOAS (METEOR, CSR), and SMR (SICH, CSR).

- 23.60 - 24.0 GHz: Primary allocation, best used to observe water vapor/liquid. Considered by some the most important of the bands around 20 GHz. Instruments affected: AMR (JASON, France/USA), AMSR (ADEOS-2, Japan), AMSR-E (EOS-PM, USA), AMSU-A (NOAA, USA; METOP, ESA), ATSR-2 (ERS-1, -2, ESA), MIMR (METOP, ESA), MSR (MOS-1B, Japan), and MWR (ENVISAT, ESA).

Other passive band concerns:

- 31.3 - 31.8 GHz: Primary allocation, best used to observe ocean ice, oil spills, clouds, and water vapor/liquid. European fixed services are threatening use of the band. Instruments affected: AMSU-A (NOAA, USA; METOP, ESA) and MSR (MOS-1B, Japan).

All bands above 71 GHz are under review for WRC-99. Details to be added summer/fall, 1998.

- 86-92 GHz: Provides a window to match sounding using the 18 GHz band. Already a PRIMARY allocation, plus active services are forbidden. No action is needed. Instruments affected: AMSR, AMSR2, AMSU-A,-B, CMHS, CMSU, MIMR, MTZA, MVZA, MZOAS, SSM/IS, and TMI.

- 115.25-122.25 GHz: Used for the 3-dimensional sounding of atmospheric temperatures using the oxygen line at 118.75 GHz. Presently PRIMARY exclusive from 105 - 166 GHz; 116-126 GHz PRIMARY shared with active services. Also, CO line at 115.221 GHz needs protection for limb sounder. Sharing studies underway. Instruments affected: AMAS, AMSR2, MILES, MLS (future), ODIN, SMILES.

- 149-151 GHz: Shared PRIMARY allocation (shared 150-151 GHz) used to observe the earth's surface, water vapor, and cloud parameters used for water vapor sounding. Should be maintained (frozen) until ~2015 to protect from active users, then relinquished. Ideally, a 2 GHz band between 142-150 GHz would be set aside. Instruments affected: AMSR2, AMSU-B, CMIU, HSB, SSM/IS.

- 155.5-158.5 GHz: Shared PRIMARY allocation (shared 156-158 GHz) used to observe the earth's surface, water vapor, and cloud parameters used for water vapor sounding. Should be maintained (frozen) until ~2015 to protect from active users, then relinquished. Interests could be served by a band around/below 150 GHz granted long-term protection. Instruments affected: AMSR2, MHS, MVZA.

- 164-168 GHz: Exclusive PRIMARY passive band used for cloud water, rain, and ice observation. Affected users: AMSR2, CMHS, and IMAS. It is unclear whether all three of the above bands are needed (149-151 GHz, 155.5-158.5 GHz, and 164-168 GHz), and if not, which is/are the best.

- 174.8 - 191.8 GHz: Needed for 3-dimensional sounding of water vapor (line at 183.31 GHz) in the atmosphere from both LEO and GEO. Shared PRIMARY from 174.5 to 176.5, PRIMARY from 182 - 185 GHz (footnoted exception in the U.K.). Extending this band to 174.5 - 191.6 GHz (17.1 GHz bandwidth) improves the atmospheric sounding capability. The availability of single-sideband receivers would almost halve this bandwidth requirement. Instruments affected: AMAS AMSR2, AMSU-B (NOAA, USA; METOP, ESA),CMHS, HSB, MHS (EOS-PM, USA; NOAA, USA; METOP, ESA), MILES, MLS (UARS, USA), MVZA, SMILES, and SSM/IS.

- Around 205 GHz (199 - 207 GHz): Spectral lines for ClO, O3, N2O, H2), and H2O2 need protection for limb sounders. Affected instrument: AMAS, MLS (UARS) and MASTER.

- Around 220 GHz: 217-231 GHz is exclusive PRIMARY for passive usage. A 4 GHz band is needed somewhere between 2178-231 GHz, the bet area is between 217-225 GHz. Spectrum outside this band could be deleted.

- Around 231 GHz, spectral lines for O3 and CO need protection for limb sounders. Affected instrument: MLS (UARS).

- Around 300 GHz (296 - 306 GHz), spectral lines for O3, N2O, O2 need protection for limb sounders. Instrument affected: MASTER.

- Around 325.15 GHz (+/- 9.0 or 9.5 GHz): Used for nadir sounding of water vapor using GEO and limb sounding using LEO. Need at least 18 GHz centered on 325.15 GHz. Instrument affected: MASTER.

- Around 340 GHz (339 - 348 GHz?): Need a relatively clear window for water vapor measurements to match the 380 GHz band. 4 GHz is needed, the best are would include 339-342.5 GHz. However, spectral lines between 342 - 348 GHz for CO and HNO3 need protection for limb sounders. Instruments affected: MASTER.

- Around 380.2 GHz (+/- 8.5 or 9.0 GHz): At least 17 GHz is needed for close-to-nadir sounding of water vapor using GEO.

- Around 424.7 GHz: Either a 2 GHz window centered at 410 GHz (409-411 GHz) and an 11 GHz band centered at 424.7 GHz (418.2-431.2 GHz), or a 17 GHz band centered on 424.7 GHz (416.2 - 433.2 GHz) is needed for close-to-nadir temperature sounding from GEO.

- Around 502 GHz (498 - 505 GHz), spectral lines for BrO, O3, N2O, H2O, ClO, CH3Cl need protection for limb sounders. Instruments affected: SOPRANO, MASTER, ODIN (down to 486.1 GHz to include O2).

- Around 557 GHz: Spectrum is needed for close-to-nadir water vapor sounding from GEO. Possibly: one 10 GHz band centered on 557 GHz (552-562 GHz) plus three 4 GHz bands centered on 540, 525, and 500 GHz. (This is a first proposal only!) Also, spectral lines for HNO3 and O3 need protection from 541 - 558 GHz for limb sounders. Instrument affected: ODIN.

- Around 570 GHz (563 - 580.4 GHz) Spectral lines for ClO and O3, as well as mesospheric H2O (547 - 584 GHz) need protection for limb sounders. Instrument affected: ODIN

- Around 625GHz: A number of spectral lines of use to limb sounders exist between 624 - 629 GHz (ClO2 at 624.271 GHz +/- 50 MHz, SO2 at 624.344 GHz +/- 50 MHz, BrO at 624.770 GHz +/- 50 MHz, O3 at 625.656 GHz +/- 300 MHz, HCl at 625.900-625.930 GHz +/- 150 MHz, CH3Cl at 627.177 GHz +/- 50 MHz, O2 at 627.773 GHz +/- 300 MHz, and HOCl at 628.460 GHz +/- 50 MHz). Instruments affected: SMILES, SOPRANO.

- Around 642.85 GHz, spectral lines of CH2Cl, ClO, BrO, HCl, HOCl, and SO2 need protection for limb sounders. Affected instrument: MLS (new).

- Around 650 GHz: Spectral lines of use to limb sounders exist between 646.8 - 653 GHz (H2O at 647.198 GHz +/- 300 MHz , Clo at 649.45GHz /-100 MHz, HO2 at 649.701 GHz +/- 50 MHz, HNO3 at 650.279 GHz +/- 50 MHz, O3 at 650.733 GHz +/- 300 MHz, NO at 651.771 - 651.773 +/- 50 MHz, and N2) at 652,834 GHz +/- 150 MHz). Instrument affected: SMILES.
- Around 953 GHz (951.6 - 955.4 GHz), spectral lines for O2 and NO need protection for limb sounders. Instrument affected: SOPRANO.

- Around 1228.95 GHz, spectral lines for HF need protection for limb sounders. Affected instrument: MLS (new).

- Around 2522.78 GHz, OH lines need protection for limb sounders. Affected instrument: MLS (new).

The following table encompasses all known bands of potential interest to the EESS above 71 GHz. **BOLDFACE-text known instruments** have been flown, are now flying, or are in preparation for flight. Normal-text instruments are on a planned mission, while *italicized-text instruments* are proposed or of unknown status (August, 1998).