10th Annual CubeSat Developers' Workshop 2013
24-26 April 2013
Cal Poly, San Luis Obispo, USA

ITU RADIO REGULATIONS
related to
SMALL SATELLITES

Attila MATAS
ITU
Radiocommunication Bureau

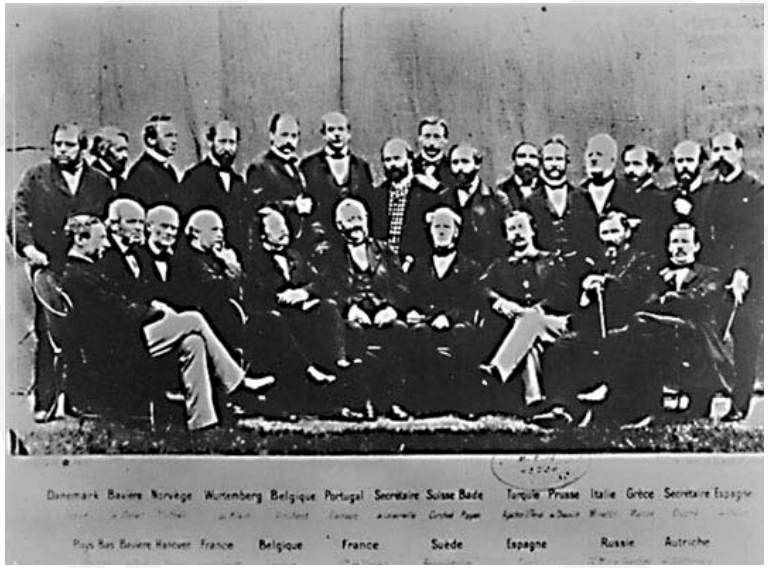
International Telecommunication Union
Committed to connecting the world

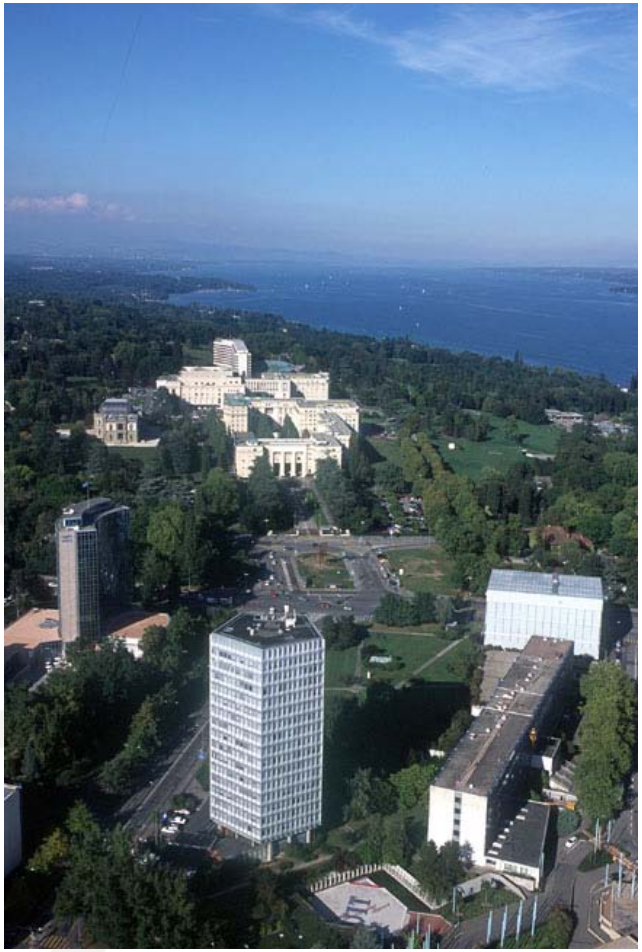
ITU in brief

Committed to Connecting the World

International Telecommunication Union

- Founded on 17 May 1865





- **193 Member States**
- **> 700 Sector Members &** Associates
- **750 staff / 70 nationalities**
- **Annual budget = $*140,000,000***
- **http://www.itu.int**

- **ITU is the leading UN agency for information and communication technologies**

ITU mission

"To ensure rational, equitable, efficient and economical use of the radio frequency spectrum by all radiocommunication services - including those using the geostationary satellite orbit or other satellite orbits - and to carry out studies on radiocommunication matters" (ITU CS 78 & 196)

Presentation outline

1. Is it *OBLIGATORY* to follow the ITU Radio Regulations?
2. *WHICH* SERVICE and FREQUENCY BAND TO USE ?
3. *HOW TO AVOID HI ?*
4. *HOW MUCH COST* an ITU NOTIFICATION ?
5. *WHAT* NEEDS TO BE NOTIFIED to the ITU?
6. *WHEN* TO INITIATE A NOTIFICATION ?
7. *HOW* TO SUBMIT A NOTIFICATION ?
8. *HOW* TO OPERATE A TT&C Earth station ?
9. SMALL SATELLITE *FUTURE*?
10. *HOW TO PARTICIPATE* in the ITU-R studies?

Radio Regulations

Committed to Connecting the World

International Telecommunication Union

- Intergovernmental Treaty – *legal bindings* on all Member states, governing the use of *spectrum/orbit* resources by administrations

- Define the *rights* and *obligations* of Member States in respect of the use of these resources
  - Principles of use of *orbit/spectrum*
  - *Allocation* of frequency bands and *services*
  - *Procedures* and *Plans*

- Updated every 3-4 years by World Radiocommunication Conference (WRC)
- Last one **WRC-12** (Geneva, Switzerland, 23 January - 17 February 2012)

http://www.itu.int/ITU-R/index.asp?category=conferences&rlink=wrc-12&lang=en

Radio Regulations -1

Committed to Connecting the World

The **ITU Radio Regulations (RR)** incorporates the decisions of the World Radiocommunication Conferences (**WRC**), including all Articles, Appendices, Resolutions, Recommendations and ITU-R Recommendations incorporated by reference.

- Two main concepts:
  - Frequency block ***allocations*** to defined radio services (**Table** - Article **5**)
  - Mandatory or voluntary ***regulatory procedures*** (Coordination, Plan, Notification) and Recording in the Master International Frequency Register (***MIFR***) that are adapted to the frequency allocation structure

Radio Regulations - 2

Committed to Connecting the World

International Telecommunication Union

Status
RIGHT for international recognition
OBLIGATION to eliminate harmful interference
Art 7-8

Frequency TABLE
(9kHz-275GHz)
Art 4-6

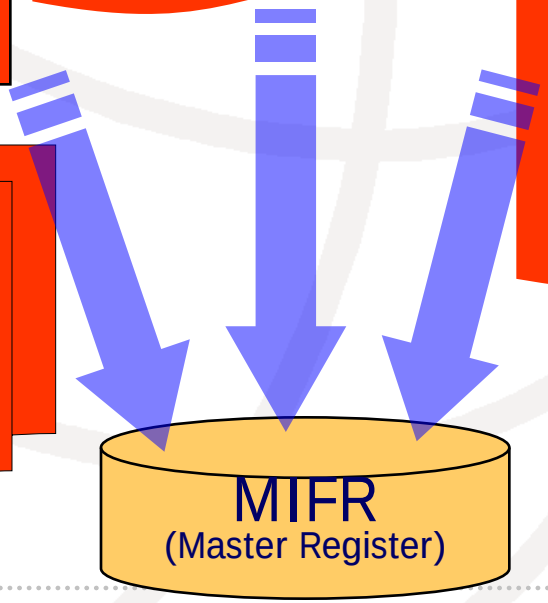
Interference & Monitoring
Art 15-16
Aps 9-10

Definitions – Art 1-3, AP 14, 42
Administrative
Secrecy/Licences/
Interception/Identification of stations/
call signs/Service Publications
Art 17-20
Bureau & RRB – Art 13-14

Procedures
Coordination,
Notification &
Recording
Art 9, 11
AP 4-8

Limits
technical/operational
Arts 21, 22
APs 1-3

Services
Aeronautical – Art 35-45
Maritime – Art 46-58
Amateur, broadcasting,
fixed, radiodetermination,
standard freq. & time – Art 12, 23-29
AP 11-13, 16, 19



Plans
Maritime HF, VHF (AP 17-18)
Maritime coast stations (AP 25)
Aeronautical (OR) (AP 26)
Aeronautical (R) (AP 27)
Broadcasting-satellite (AP 30-30A)
Fixed-satellite (AP 30B)

GMDSS
Art 30-34
AP 15

- **Objectives:**

➢ to facilitate *equitable access to* and *rational use* of the natural resources of the *radio-frequency spectrum* and *any associated orbits*;

➢ to ensure the *availability and protection* from harmful interference of the frequencies provided for *distress and safety purposes*;

➢ to assist in the *prevention and resolution of cases of harmful interference* between the radio services of different administrations;

➢ to facilitate the *efficient and effective operation of all radiocommunication services*;

➢ to provide for and, where necessary, *regulate new applications* of radiocommunication technology.

Propagation of Radio waves

- Laws of physics
- Radio waves *do not stop at national borders*

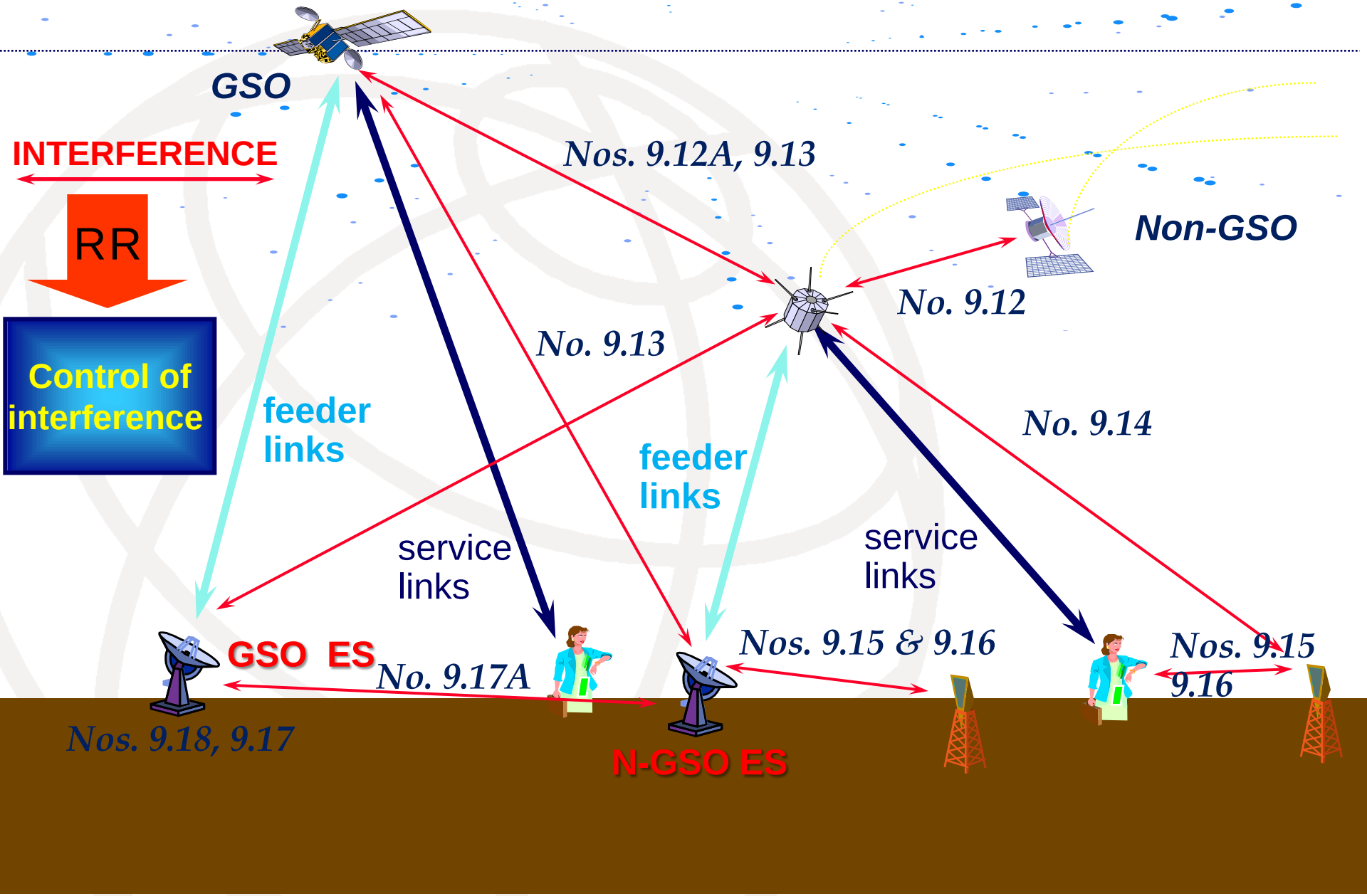
Interference

- *Possible* between radio stations of *different countries* and/or different services
- This risk is *high* in Space Radiocommunications

Radio Regulations

- One of its main purposes - ***Interference-free operation of Radiocommunications***

Non-GSO Coordination provisions



Radio Regulation Mechanisms

Control of Interference

ALLOCATION

Frequency separation of stations of different services

POWER LIMITS

PFD to protect TERR services
EIRP to protect SPACE services
EPFD to protect GSO from N-GSO
(EPFD = aggregate equivalent power flux-density)

REGULATORY PROTECTION

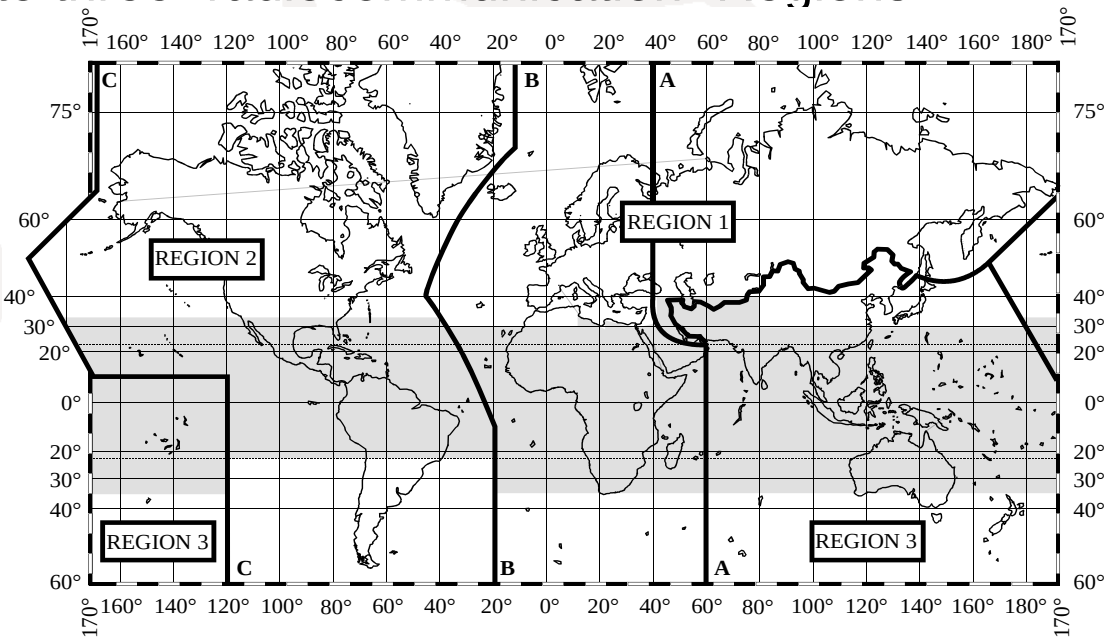
e.g. No. **22.2**: Non-GSO to protect GSO (FSS and BSS)

COORDINATION

between Administrations to ensure interference-free operations conditions

ART 5 frequency allocations - 1

- No. **5.2** - For the allocation of frequencies the world has been divided into three “radiocommunication” Regions



➢ *Exclusive allocations*, which are favoured in cases that involve *broad international use of equipment*

➢ *Shared frequency allocations*, which are applied to maximize the use of the available spectrum when *two or more radiocommunication services can effectively utilize the same frequency band*

WHICH SERVICE and FREQUENCY BAND TO USE ?

ART 5 frequency allocations - 2

- A *shared* frequency band can be allocated to more than one service (*PRIMARY* or secondary), either on a worldwide or Regional basis
- No. **5.28 -** Stations of a *secondary service*:
  - **5.29 -** *shall not cause harmful interference to* stations of PRIMARY services to which frequencies are already assigned or to which frequencies may be assigned at a later date;
  - **5.30 –** *can not claim protection from* harmful interference from stations of a PRIMARY service to which frequencies are already assigned or may be assigned at a later date;
  - **5.31 -** *can claim protection*, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.
- A *footnote* to a frequency band or service *may include a restriction* on the service or services concerned
  - to operate in a particular country(ies) or service area
  - not causing harmful interference to another service
  - not claiming protection from another service

ART 5 frequency allocations - 3

144–146 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
144-146	AMATEUR AMATEUR-SATELLITE 5.216	

5.216 *Additional allocation:* in China, the band 144-146 MHz is also allocated to the aeronautical mobile (OR) service on a secondary basis.

430–440 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
430-432 AMATEUR RADIOLOCATION 5.271 5.272 5.273 5.274 5.275 5.276 5.277	**430-432** RADIOLOCATION Amateur 5.271 5.276 5.277 5.278 5.279	
432-438 AMATEUR RADIOLOCATION Earth exploration-satellite (active) 5.279A 5.138 5.271 5.272 5.276 5.277 5.280 5.281 5.282	**432-438** RADIOLOCATION Amateur Earth exploration-satellite (active) 5.279A 5.271 5.276 5.277 5.278 5.279 5.281 5.282	
438-440 AMATEUR RADIOLOCATION 5.271 5.273 5.274 5.275 5.276 5.277 5.283	**438-440** RADIOLOCATION Amateur 5.271 5.276 5.277 5.278 5.279	

5.282 In the bands 435-438 MHz, 1260-1 270 MHz, 2 400-2 450 MHz, 3 400-3 410 MHz (in Regions 2 and 3 only) and 5 650-5 670 MHz, the amateur-satellite service may operate subject to not causing harmful interference to other services operating in accordance with the Table (see No. **5.43**). Administrations authorizing such use shall ensure that any harmful interference caused by emissions from a station in the amateur-satellite service is immediately eliminated in accordance with the provisions of No. **25.11**. The use of the bands 1 260-1 270 MHz and 5 650-5 670 MHz by the amateur-satellite service is limited to the Earth-to-space direction.

ART 5 frequency allocations - 4

890-1 300 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
890-942 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 Radiolocation	**890-902** FIXED MOBILE except aeronautical mobile 5.317A Radiolocation 5.318 5.325	**890-942** FIXED MOBILE 5.317A BROADCASTING Radiolocation
	902-928 FIXED Amateur Mobile except aeronautical mobile 5.325A Radiolocation 5.150 5.325 5.326	

Amateur service in the band 902-928 MHz is a *secondary service in Region 2 only* – ***this is not an amateur satellite service allocation !!***

ART 5 frequency allocations - 5

No. **1.15** *industrial, scientific and medical (ISM) applications* (of radio frequency energy)*:* Operation of equipment or appliances designed to ***generate and use locally radio frequency energy*** for industrial, scientific, medical, domestic or similar purposes, ***excluding applications in the field of telecommunications***

No. **5.150** The following bands:

……..

902-928 MHz in Region 2 (centre frequency 915 MHz),

2 400-2 500 MHz (centre frequency 2 450 MHz),

……

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. **15.13**.

No. **15.13** § 9 Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service…..

Radio services - Class of Station

Typical Non-GSO small satellite services

See Article **1** – Section III of the RR and the Preface – Table 2 : http://www.itu.int/ITU-R/space/preface/

- **E1** - Space research (active sensor) space station
- **E2** - Space research (passive sensor) space station
- **E3** - Space station in the Earth exploration-satellite service (active sensor)
- **E4** - Space station in the Earth exploration-satellite (passive sensor)
- **EA** - Space station in the amateur-satellite service
- **EH** - Space research space station
- **EW** - Space station in the earth exploration-satellite service

HOW TO AVOID HI ?
HOW MUCH COST
an ITU NOTIFICATION ?

N-GSO small satellite design

Careful planning of services, service area, frequency bands and link budget gives to your satellite projects the best chance to operate your satellite interference free !

- Using the Table, as a starting point, of each country selects *appropriate frequencies* with a view to assigning them *to stations of a given service*
- The regulatory authority concerned and users should be aware of *all conditions regulating the use of frequencies in the band concerned*:

➢ Is Article **25** (Amateur-satellite service) *applicable* and ***all requirements are met ?***

✓ No. 1.56 *amateur service:* A *radiocommunication service* for the purpose of *self training, intercommunication and technical investigations* carried out by amateurs, that is, by *duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest*

✓ No. *25.6 Administrations shall verify the operational and technical qualifications of any person wishing to operate an amateur-satellite station.*

✓ No. 25.11 *Administrations authorizing space stations in the amateur-satellite service shall ensure that sufficient earth command stations are established before launch to ensure that any harmful interference caused by emissions from a station in the amateur-satellite service can be terminated immediately (see No. 22.1)*

➢ Is there *a need for effecting the coordination procedure prior to notification?*

➢ Is the RR provision or procedure *mandatory* or voluntary?

➢ Is there *a need to notify* the frequency assignment to the Bureau?

➢ *Cost recovery fees* - API for non-GSO/570 CHF and Notification/7030 CHF (no cost recovery charges for the publication of Special Sections for the amateur-satellite service)

WHAT NEEDS TO BE NOTIFIED to the ITU?

WHAT NEEDS TO BE NOTIFIED ?

- ***Any*** frequency assignments of transmitting and receiving earth and space stations ***shall be notified*** to the Bureau (No.**11.2**) if:
  - Capable of causing harmful interference; or
  - Used for international radiocommunication; or
  - Subject to coordination procedure of Article **9**; or
  - Seeking to obtain international recognition; or
  - Non conforming assignment under No. **8.4** seeking to be recorded into **MIFR** for information purposes only

API procedure - 1

- No. **9.1** of the RR stipulates that **before initiating any action under Article 11** (Notification) in respect of frequency assignments for a satellite network, *an administration shall send to the Bureau* a general description of the network for **API** publication *not earlier than seven years* and preferably *not later than two years* before the planned *date of bringing into use (DBiU)* of the satellite network or system

- API phase is ***obligatory***

- No priority in being first to start API

- Starts the ***"regulatory clock" for notification***

API procedure - 2

- **Non-GSO small satellites** *are generally systems which are not subject to any form of mandatory coordination (Article 9 of the RR)*

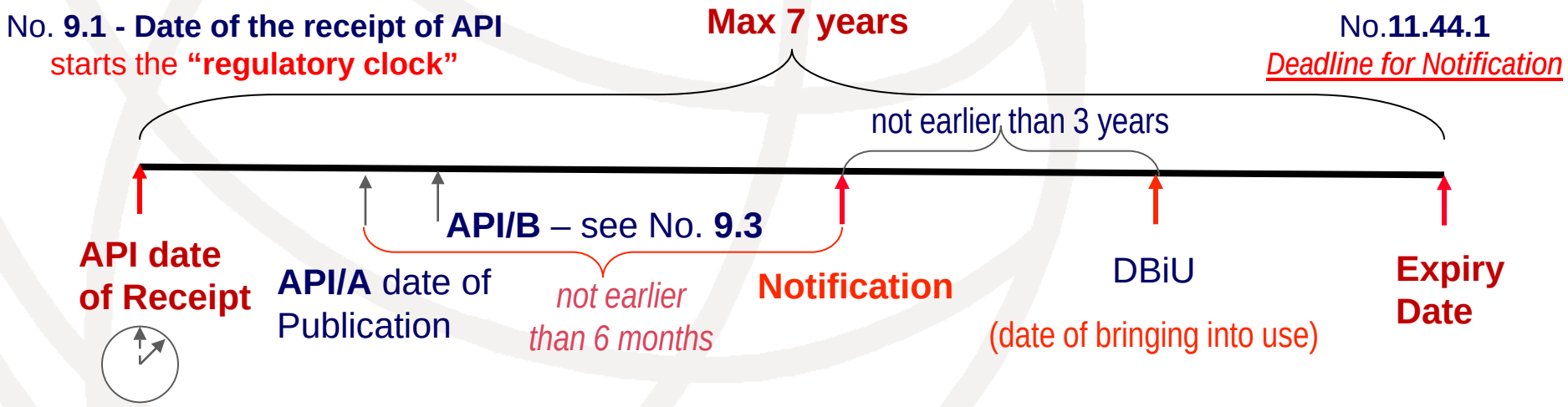
  - For such systems, the provisions of *Article **9**, Sub-Section **IA*** (API on satellite networks that are not subject to coordination procedure under Section **II),** *are applicable*.

  - *Administrations are reminded also of No. **9.3** of Article **9***, relating to comments by administrations on **API/A** publications for a satellite network that is not subject to the coordination procedure under Section **II** of Article **9,** and of No. **9.5**, *relating to the treatment by the Bureau of such comments* (publication of Special Section **API/B**)

WHEN TO INITIATE A NOTIFICATION ?

WHEN TO INITIATE THE NOTIFICATION PROCEDURE ?

- Generally *after the completion of the Advance Publication procedure (**API**)*
- No. **11.25** - Notices relating to assignments to stations in space services - *not earlier* than *three years before the assignments are brought into use* (DBiU)
- Nos.**11.44** and **11.44.1** - The first notice for recording of the space station frequency assignments *must be carried out and brought into use before the end of 7 years* from the date of receipt of **API** information under No. **9.1**



Notification procedure (ART 11) - 1

- The international ***rights*** and ***obligations*** of the administrations in respect of their own satellite systems and of other administrations' frequency assignments are derived ***from the recording*** of their assignments in the **MIFR**

- Administrations shall provide the relevant characteristics as specified in Appendix **4** (No. **11.15**)

- A complete notice is published in **PART I-S** of the BR IFIC with the date of receipt. *This publication shall constitute the acknowledgement to the administration of receipt of its notice.*

- **PART I-S** notice is used for further technical and regulatory examination by the Bureau

Notification procedure (ART 11) - 2

- **Technical and regulatory examination by the Bureau**
  - No. **11.31**- conformity with the Table and other provisions of the RR
  - When No. **11.31** finding is favourable, the assignment shall be recorded in the **MIFR** (if Nos.**11.32-11.34** are not applicable)
  - **PART II-S** - *Favourable Findings* adopted concerning new frequency assignments or modifications to existing frequency assignments resulting in the recording of the frequency assignment in the MIFR;
  - **PART III-S** - *Unfavourable Findings* adopted concerning new frequency assignments or modifications to existing frequency assignments resulting in the return of the notice to the notifying administration.
  - **All Special Sections (API or CR/C) and PARTs are published in the BR-IFIC (Space services) DVD-ROM** (http://www.itu.int/ITU-R/go/space/en)

HELP !!
HOW TO SUBMIT A NOTIFICATION ?

ITU-R small satellite CD-ROM - 1

- ITU Regulatory Framework for small satellites, nanosatellites and picosatellites
- Frequency registration for small satellites including API & Notification wizards

Other documents

(Please note that all information in this Table are related to *Amateur-satellite service only*)

- ITU-R Circular Letter CR/303

  Available in 6 languages at: http://www.itu.int/md/R00-CR-CIR-0303

- ITU BR Registration Tutorial *for a potential amateur-satellite builder team*
- Typical applications of frequency bands
- ITU Radio Regulations, edition 2012 (on the CD-ROM, on the ITU website)
- Article 25 of the RR – Amateur and Amateur-satellite services
- RESOLUTION 757 (WRC-12) - Regulatory aspects for nanosatellites and picosatellites
- RESOLUTION 642 (WARC-79) - Relating to the bringing into use of earth stations in the amateur-satellite service
- BR software for Space data capture, validation, query and print
- Preface

  Available in 6 languages at: http://www.itu.int/en/ITU-R/space/Pages/prefaceMain.aspx

- Amateur and amateur-satellite services Handbook

(This Handbook provides general information about the amateur and amateur-satellite services. It also includes a compendium of existing ITU texts of relevance to the amateur and amateur-satellite services.) *Available from the ITU Bookshop at:* http://www.itu.int/publ/R-HDB-52/en

ITU-R small satellite CD-ROM - 2

Examples of small satellite filings

- BRITE
  - API/A
  - API/B
- BRITE-PL
  - API/A
  - API/B
- TISAT-1
  - API/A
  - API/B
  - PART I-S
  - PART II-S
- SWISSCUBE
- M-CUBED
  - API/A
- TECHEDSAT1
  - API/A
- WE WISH
  - API/A, API/A MOD-1
  - API/B
- PRISM2
  - API/A, API/A MOD-1
  - API/B
  - PART I-S
  - PART II-S
- CUTE-I
  - API/A
  - PART I-S
  - PART II-S

You can consult these and other NON-GSO sample networks by using Spacequery or Spacecap to view the file SRS-non-GSO-2012.mdb on the CD

1

API, Coordination and Notification software tools

Free data Capture tools are available from the ITU website:
http://www.itu.int/ITU-R/software/space/

Notification Software Tools & Aids	Description
Space Capture Software (SpaceCap) (recommended)	PC-based software for electronic capture of **AP4** forms of notices for API, CR or Notification
Space filing Validation Software (SpaceVal) (mandatory)	PC-based software for validating electronic notices captured by the SpaceCap software
Space data Query Software (SpaceQry)	PC-based software package which allows the query/access to the Bureau's Space Radiocommunication Stations database
Space Publication Software (SpacePub)	PC-based software utility for printing satellite networks / earth stations data

More on-line HELP and useful links

Free on-line ITU-R help & documents

- **ITU Radio Regulations @ 2012:**

  http://www.itu.int/pub/R-REG-RR-2012

- ***Support to Amateur Satellite service:***

  http://www.itu.int/en/ITU-R/space/Pages/SupportAmateur.aspx

- **ITU-R Recommendations:**

  http://www.itu.int/publ/R-REC/en

Space Network List (SNL)

The Space Network List (SNL) on-line

http://www.itu.int/ITU-R/space/snl/

- A *list of basic information* concerning planned or existing space stations, earth stations and radio astronomy stations
- Set up in **3 Parts** to provide ADMs and other users with information:
  - on the **use of the frequency spectrum** and
  - the **occupancy of the GSO** as well as on **non-GSO orbits** (***Part A***)
  - to **keep track on reference publications** (PARTs and Special Sections) (***Part B***)
  - on pending networks (backlog) (***Part C***)
- ***FREE SERVICE*** (bi-weekly updated)

Small satellite statistics

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Number of API	3	10	9	4	11	8	8	8	35	43

- The Bureau identified **545** non-GSO satellite networks in the ITU-R SRS data base (version **31.12.2012**), among which **87** non-GSO satellite networks might be identified as “nano and pico” satellite networks. Caution has to be exercised regarding the above numbers of “nano and pico” satellite networks filed at the Bureau in the absence of a clear definition for such satellite networks in the ITU Radio Regulations (RR)
- Based on Bureau’s experience on satellite notices submitted by administrations, most of the “nano and pico” satellite networks are declared under amateur-satellite service - Class of station **EA**, using frequency bands where **EA** is a PRIMARY service or in the bands where **EA** is authorized to operate under No. **5.282**
- Some advance “nano and pico” satellites with a camera or a sensor on board use for high speed data download are also operating in the part of the S band allocated to space research service (**EH**) and for TT&C use **EA** frequency bands;
- New generation “pico and nano” satellites with advance sensors are also using frequency bands allocated to land-mobile (**EU**) or earth exploration (**EW**) satellite service

HOW
TO OPERATE
A TT&C Earth station ?

Small satellite ground segment - 1

- In conformity with No. **25.11** of the RR, any amateur-satellite operator shall set up at least one TT&C station to ensure that any harmful interference caused by emissions from its satellite can be terminated immediately (see No. **22.1**). This TT&C station, have to be operated by an operator with a valid amateur license (duly authorized person) (Nos. **1.56** and **1.57** and **ART 25** of the RR) and callsign (**ART 19** of RR)
- TT&C station is a critical part of the amateur-satellite systems with several technical and operational challenges.
  - low output power of the transponder and simple antennas on the satellites
  - a need to use 2x or 4x times stacking of multiple cross-polarisation high-gain antennas with automatic azimuth/elevation tracking system capable to apply frequency corrections to the radio to compensate for Doppler shift
  - the visibility/access time (in-view window), of a satellite for a given Earth station is very short due to low orbit height and varies from approximately 10-15 minutes in the best case to no coverage at all for most of the 16 daily orbits
- For the above mentioned reasons some operators are planning to improve this situation by setting up an Internet connected special dedicated network of numerous/multiple remote amateur-satellite Earth stations along its satellite track (instead of one amateur-satellite Earth station, waiting for downlink opportunities) to increase a satellite availability and to extend access time and practically to have a global coverage, *capable to track and download telemetry or mission science data from the satellite at any place and any time if at least one "networked" Earth station can see (in-view-window) the satellite*

Small satellite ground segment - 2

- In most cases the “networked” remote amateur-satellite Earth stations are outside of its satellite service area and administrations *very rarely* notify this “extended service area” in the satellite networks notices. This missing information may generate a harmful interference situation when the amateur-satellite is operating in the bands shared with other services (No. **5.282**) on a non-interference basis and the satellite is “active” (transmitting with a high power) *outside of its service area*
- Administrations may authorize operation of these specific amateur-satellite Earth stations, which can receive the telemetry or mission science data from any amateur-satellite and send this data by Internet to the particular amateur-satellite Mission Control Centre. However, to protect frequency assignments and gain international recognition of such amateur-satellite Earth stations in application of Resolution **642** (WARC-97), administrations should under No. **11.2** notify these Earth stations to the Bureau
- In contrary, it’s necessary to note that a *remote transmission (uplink) by Internet and remote utilisation of another specific amateur TT&C earth command station for transmission (uplink) is prohibited*, *unless the Administrations concerned authorize it*.
(See Resolution **1** and ART **18** of the RR)

SMALL SATELLITE *FUTURE ?*

Preliminary Agenda WRC-18

Resolution **757 (COM6/10)** (WRC-12)

Regulatory aspects for nano- and picosatellites

resolves to invite ***WRC-18***

to consider *whether modifications to the regulatory procedures for notifying satellite networks are needed* to facilitate the deployment and operation of nano- and pico satellites,

and ***to take the appropriate actions***

Resolution 757 (WRC-12)
Regulatory aspects for nano- and pico satellites

invites ITU-R

- to examine the procedures for notifying space networks and consider possible modifications to enable the deployment and operation of nano- satellites and pico satellites, taking into account the short development time, short mission time and unique orbital characteristics,

instructs the Director of the Radiocommunication Bureau

- to report to WRC-15 on the results of these studies

ITU-R Question 254/7

Characteristics and spectrum requirements of satellite systems using nano and pico satellites

- The ITU Radiocommunication Assembly,
  decides that the following Questions should be studied:

1. What are the distinctive characteristics of nano and pico satellites and satellite systems in terms of their use of the radio spectrum as defined by data rates, transmissions time and bandwidths?
2. Taking into account such distinctive characteristics, what are the spectrum requirements for nano and pico satellite systems?
3. Under which radiocommunication services can satellite systems using nano and pico satellites operate?

- *further decides*

1. that the results of the above studies should be included in one or more Recommendation(s) and/or Report(s);
2. that the above studies should be completed by 2015.

HOW TO PARTICIPATE in the ITU-R nano and pico satellite studies?

Resolution 757 (WRC-12)
Regulatory aspects for nano- and pico satellites

invites administrations and Sector Members

- to participate actively in the studies by submitting contributions to ITU-R

HOW your university can *actively participate* in these studies??

- Contact your national Telecommunication Regulatory body

OR

- *Become an ITU Academia member* (ITU brings together more than **700 Sector Members and Associates** from industry, international and regional organizations, **as well as academia**. In doing so, ITU provides a unique, trusted and global multi-stakeholder platform for partners from the public and private sectors to address major ICT issues)

For more info - http://www.itu.int/en/membership/Pages/sector-members.aspx

ITU RADIO REGULATIONS

related to

SMALL SATELLITES

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Questions ?

International Telecommunication Union

Committed to connecting the world