Frequency Regulations Management for Educational Small-Satellite Programmes

Experience from the ESA CubeSat Programme

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Presentation Outline

1. Overview of the ESA CubeSat Programmes
2. The need for guidelines on regulatory matters
3. Innovative Approach considering Law and Regulation
4. Deliverables, Evaluation and Examples
1. The **Education and Knowledge Management Office** is engaged in:
   
   a. Tertiary Education projects
   b. Primary/Secondary Education activities
   c. Communication and Outreach
   d. Knowledge Management

2. **Tertiary Education project initiatives** include:
   
   a. REXUS / BEXUS
   b. Drop Your Thesis / Spin Your Thesis
   c. New CubeSats activities: “Fly Your Satellite”
   d. ESEO entering pre-phase C with AlmaSpace selected as System Prime

For more info: [http://www.esa.int/Education](http://www.esa.int/Education)
First ESA CubeSats project for the Vega Maiden Flight: Launched on 13. February 2012

**SPAIN**
- XatCobeo, Uni. Vigo
  (Software-defined radio; solar panel deployment)

**ROMANIA**
- First National Satellite
- Goliat, Uni. Bucharest
  (Earth imaging; space environment measurements)

**FRANCE**
- Robusta, Uni. Montpellier 2 (Radiation effects on bipolar transistors)

**POLAND**
- First National Satellite
- PW-Sat, Warsaw Uni. Of Technology (Deployable drag augmentation device)

**ITALY**
- E-St@r, Politecnico di Torino (Test an active 3-axis Attitude Control)

**HUNGARY**
- First National Satellite
- MaSat-1, Budapest Uni. of Technology
  (s/c power; communication; on-board data handling)

**ITALY**
- UniCubesat, Roma
  (Gravity Gradient boom deployment)
Identification of the Issue: CubeSats for the Vega Maiden Flight

CubeSats for Vega Maiden Flight

- First ESA CubeSat project
  - Involved in technical/test aspects and flight preparation
  - Launch of 7 CubeSats
  - All using radio-amateur frequencies

- **Identified Issues regarding law and regulation:**
  - Not all on-board CubeSats were properly registered at ITU
  - Question of compatibility of the satellite frequencies
  - Several CubeSats were not operational on orbit
  - Lack of awareness on responsibilities with CubeSat teams
Fly Your Satellite is an educational CubeSat programme, carried out by the ESA Education Office

- Offer **expertise support from ESA technical specialists**
- Emphasize on the importance of **verification** and of having **good documentation**, as key methodologies to improve chances of mission success
- Provide **access to State of the Art environmental test facilities** (vibrations and thermal vacuum)
- Facilitate the procurement of a launch opportunity for the CubeSats that finally will be selected for the “**Ticket to Orbit!**”

Aim of the Fly Your Satellite! (FYS) programme:
http://www.esa.int/Education/Call_for_Proposals_Fly_Your_Satellite
Fly Your Satellite!: Programme Structure

Call for Proposal released on the ESA Education webpage: January 2013 – Closed on 1st March 2013

Key eligibility criteria: CubeSat teams at an advanced stage of development with Flight Model assembled around June 2013; compliance with CDS rev.12; educational objectives; nationality requirements; ...

Selections: At each phase, not necessarily all teams are selected to pass to next phase

Kick-off Workshop: June 2013

The programme is structured in 4 phases:

Phase 1 – “Build your Satellite”
  Phase 1A: “Satellite integration”
  Phase 1B: “Functional tests – Ambient”

Phase 2 – “Test Your Satellite”
  Phase 2A: “Environmental Tests Preparation”
  Phase 2B: “Environmental Tests Execution”

Phase 3 – “Ticket to Orbit”
  Phase 3A – “Acceptance tests campaign”
  Phase 3B – “Launch Preparation campaign”

Phase 4 – “CubeSats in Space”
  Phase 4A – “Launch Event and Early Operations Phase (EOP)”
  Phase 4B – “CubeSats Operations Results feedbacks”
**Fly Your Satellite!: Participating CubeSats Phase 1**

**BELGIUM**
OUFTI-1, Liège (1U)
*Test D-STAR amateur radio protocol in space*

**SPAIN**
Politech.1, Valencia (3U)
*C-band communication, Earth Imaging, solar wind experiments*

**FRANCE**
Robusta-1B, Montpellier (1U)
*Radiation effects on bipolar transistors*

**CANADA**
ConSat-1, Montreal (3U)
*Radiation measurements, Technology demonstration*

**ITALY**
E-St@r-II, Torino (1U)
*Test an active 3-axis Attitude Control*

**DENMARK**
AAUSAT4, Aalborg (1U)
*AIS receiver, AOCS tech demonstrator*
Rationales for Law and Regulations Documentation

• Innovative educational approach for CubeSat programmes:
  *Technology BUT also Law and Regulation*

• CubeSat are official national space activities

• Interconnection between use of technology and regulations = regulation aspects are equal part of satellite project planning

• Existence of internationally binding rules in telecommunication and particularly regarding space objects

• All states are members of ITU Constitution and Convention = national governance/regulation

• Specific issues: Use of radio-amateur frequencies (specific rules), national space law and policies etc.

Authors: Daniel Sagath and Joost Vanreusel
FYS Kick-off Workshop (June 2013)

- Frequency coordination and registration already involved
- Several introductory presentations made by top representatives of:
  - ITU (frequency registration)
  - IARU (radio-amateur frequency coordination)
  - ESA (space object registration)
- Because these issues are rather complex and difficult, teams highly appreciated this topic to be included in the FYS programme
- Result: Guidelines preparation and further expert’s advices

But why is necessary to talk about the frequency management already during the early phases of CubeSats projects?
Practical Reasons for Frequency Management

- Radio frequency planning at the beginning of a satellite project means **fewer design changes, lower project costs** and **limitation of unexpected last-moment complications** with satellite **licensing for launch**.
- Prevention of possible **frequency interference**
- When **communication** with CubeSat fails, it is DEFINITE end of its mission
- Careful and precise planning of the **ground station** and **TT&C**, data receiving (uplink/downlink) or secure other services
- Early and precise planning of **electro-magnetic compatibility** of on-board instruments
- In multi CubeSat missions the frequency **coordination** (frequency bandwidth) is appreciated
- Registration at ITU = **international protection**
Regulatory Reasons for Frequency Management

- All ITU Member States are **bound to abide** the provisions of ITU Constitution (No. 6.1 of ITU Constitution)
- Frequency is **limited natural resource** and must be used rationally, efficiently and economically (No. 44.2 Ibid)
- All stations must be established and operated in such a manner as **not to cause harmful interference** (No. 45.1 Ibid)
- Member States shall **endeavour to limit the number of frequencies** and the spectrum used to the satisfactory minimum (No. 44.1 Ibid)
- Satellites operational in secondary service (e.g. CubeSats) **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 (No. 5.29 ITU Radio Regulations)
- Satellites operational in secondary service **cannot 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 (No. 5.30 Ibid)
Satellite systems in amateur-radio service are subject to the frequency assignment notification and recording procedures (ITU CR/303)

All transmission shall be capable of being identified (No. 19.1 ITU Radio Regulations)

All transmissions with false or misleading identification are prohibited (No. 19.2 Ibid)

Space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by telecommand (No. 22.1 Ibid)

Sufficient Earth command station is established before launch (No. 25.11 Ibid)

All stations operating in the amateur service and the amateur-satellite service, including space stations and Earth stations, must be controlled by duly authorised persons, that is, individual licensed amateur radio operators (Licensees) acting solely with a personal aim and without pecuniary interest (e.g. commercial use). (No. 1.56 Ibid)
Preparatory Steps For Frequency Registration and Coordination

1. **Check the list of international treaties** ratified by your country, considering space activities and satellite missions (e.g. ITU Constitution and Convention, UN space-related treaties, etc.)

2. **Identify the appropriate governmental entity** of your country responsible for the communication with international organisations (e.g. national telecommunication regulatory authority, Ministry of Foreign Affairs, Permanent Mission to UN, national space agency)

3. **Contact the appropriate telecommunication governmental entity** and inform them about your activities

4. **Identify the appropriate radio amateur organisation** of your country and inform them about your activities (recommended step)

5. **Create an overview**, tailored to your country, of the legal practices and required administrative procedures relating to legal and regulatory aspects of satellite missions (FYS Registration Status Report)
Step 1: National Telecommunication Administration

1. **Verify** that the project meets **Article 25** (Amateur Services) of the ITU Radio Regulations and **contact** the national telecommunication administration, informing it about the planned activities and **providing proof** of the radio-amateur licence of the ground station operator.

2. **Obtain**, from the national telecommunication administration, a **proposal** for use of a specific frequency band.

3. **Contact** the **IARU Satellite Advisor** to jointly assess the suitability of the proposed frequency band.

4. **Obtain**, from the national telecommunication administration, the **licence for the frequency band** as well as the **call sign of the amateur space station** (satellite) and the **call sign of the ground station** (if it does not exist yet).
Step 2: ITU Advance Publication of Information

1. **Prepare the necessary information** and provide it to the national telecommunication administration, which shall submit the API/A filing to the Bureau. The Bureau will then publish an API/A special section in its International Frequency Information Circular.

2. Wait for **eventual publication** by the Bureau of API/B and if an API/B is published, solve any issues/comments raised by other administrations.

3. It is **strongly recommended** to follow the ITU RR and submit the basic information about the CubeSat project at the beginning
   - avoid unnecessary time constraints and pressure on the CubeSat operator before it’s satellite coordination and launch
   - avoid further questions related to the legal aspects of the project.

   **Launch provider may refuse to launch the CubeSat if it is not properly registered at the ITU**

4. The data submitted through an API **may still be changed** (e.g. orbit parameters, launch date) before the Notification, with exception of the modification of the direction of transmission etc. (see No. 9.2 of the ITU RR).
Step 3: IARU Frequency Coordination

Submit the IARU coordination filing. The filing will be handled by IARU and published on www.amsat.org.uk/iaru.

Reason for coordination:

- Radio amateur frequency coordination is the process of communicating with other radio users to minimise the chances of causing interference.
- In practice, many different and, often, incompatible operations are conducted in frequency bands allocated to the amateur service and amateur-satellite service.
Step-by-Step Approach (4/4)

Step 4: ITU Notification

1. Through the national telecommunication administration, **notify to the Bureau the frequency assignment** of the amateur-satellite service. It will then be entered in the ITU Space Master International Frequency Register (SMIFR), securing and protecting the use of your frequency.

2. ITU SMIFR Register:
   - SNL online is a list of **basic information** database of the ITU-R concerning **planned or existing space stations, earth stations and radio astronomy stations**. It includes sections on API, coordination requests and notifications.
   - The ITU-R Space Network List (SNL) allows users to build a query and can also provide satellite builders with information considering **actual/regulatory status of the API/Notification** of their particular or any other satellite networks.
Delivery of Registration Status Report

- Each team requested to prepare a Registration Status Report of their project.
- The structure of each report follows the requirements stated in the Registration Guidelines (e.g. Preparatory Steps for registration and coordination, Step-by-Step Approach etc.).
- According the information provided, the FYS project management obtained important information about each individual CubeSat regarding the legal and regulatory requirements.
- Where necessary, actions were assigned to ensure compliance with international regulations.
- Other aspects:
  - Broad description of the national legal, regulatory and policy environment and requirements in the six different countries
  - Important feedback on understanding of frequency management regarding CubeSat projects.
FYS Registration Status Reports: Evaluation Methodology

Set up simple excel table, which consists of:

1. **Vertical axis**: Team A, B, C, ...
2. **Horizontal axis**:
   - State (country)
   - Name and Date of the Registration Status Report
   - Frequency Band – uplink
   - Frequency Band – downlink
   - Frequency Bandwidth
   - Beacon
   - Payload requirements (communication instruments)
   - Call Sign – satellite
   - Call Sign – ground station
   - National telecommunication bureau
   - Governmental entity responsible for space activities (agency, office etc.)
   - IARU coordination filing (date)
   - ITU API/A or API/B registration filing (date)
   - National space object register (date)
   - UN space object register (date)
   - Special comments on Registration Report
   - Proposed action to be taken
Example 1: Coordination of frequencies

Early identification of potential issues based on **coordination** of frequencies between teams.

**Issue:** Two CubeSats using UHF frequencies in **close range** (but no overlap)

**Risk:** ‘Blind’ or damage other satellite / interference

=> **performance degradation**

**Result** Verification of **intersatellite compatibility** ongoing
(e.g. out of band emissions, receivers max RF level)
### Example 2: Cessation of emissions

<table>
<thead>
<tr>
<th>Original design:</th>
<th>In case of failure of the on-board computer (OBC), a CW beacon would be <strong>automatically transmitted</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESA review:</strong> possible violation of <strong>ITU RR No. 22.1</strong></td>
<td>“Space stations shall be fitted with devices to ensure immediate <strong>cessation</strong> of their radio emissions by telecommand, whenever such cessation is required under the provisions of the Regulations.”</td>
</tr>
<tr>
<td><strong>Team solution:</strong></td>
<td>New, specific, <strong>command</strong> implemented and tested to stop radio transmission. This command can be <strong>executed directly</strong> by the communication system (even in case of OBC failure).</td>
</tr>
</tbody>
</table>

### Result:

- **Nominal operation:**
  Command to OBC to enter « silent mode » to stop transmission.

- **Failure which stops OBC-COMSYS internal communication:**
  COMSYS automatically sends CW beacon to Earth.

- **Request to cessate transmission:**
  Command « STOP CW » sent directly to COMSYS.
Outlook

1. Law and regulation aspects were demonstrated to be as important as project planning and management even for CubeSat programmes.

2. FYS Guidelines allowed to raise the awareness regarding legal and regulation requirements, according to feedbacks received from the participating teams.

3. Proper frequency management may allow to identify additional technical problems for which new technical solutions may be investigated.

4. If registration procedures are properly followed as well as completed on time, they do not represent a demanding overload within the project framework.

5. Can contribute to further discussion and classification of specific issues regarding CubeSat projects.
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Thank you for your attention!