IDEAS FOR EXPLORING THE MOON WITH A LARGE EUROPEAN LANDER

LunaART – Luna Amateur Radio Transponder

A Communications Platform on the Large European Lander to support communication and payload experiments

AMSAT Deutschland (AMSAT-DL)

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Background information:

Worldwide AMSAT organizations, with their large community of amateur radio operators, have a rich history of pioneering science achievements in various fields of space and satellite communication from LEO to HEO, even beyond earth orbit. Starting with the 1st so-called OSCAR 1 (Orbiting Satellite Carrying Amateur Radio) launched in 1961, to the largest spacecraft build by a private non-profit organisation in 2000, the AMSAT P3-D OSCAR-40 satellite launched on Ariane 5. Amateur radio also has a permanent presence on the international space station ISS (ARISS) and plans are under way to provide a permanent amateur radio station for the Lunar Orbital Platform-Gateway (AREx) together with international partners. Given our outstanding relationship with international space agencies and with schools and universities, the amateur radio community could serve as an ambassador for space activities at the educational level (primary schools up to universities).

References of AMSAT-DL:

AMSAT Deutschland e.V. (in short AMSAT-DL) is a registered non-profit charitable organization of volunteers with different backgrounds from professional to academic levels and well experienced in designing, building and operating satellites and hosted payloads in co-operation with international teams:

- AMSAT Phase 3-A (HEO) launched on Ariane 1 flight L02 in 1980 (lost due to launch failure)
- AMSAT Phase 3-B (HEO, OSCAR-10) on Ariane 1 flight L06 in 1983, 140kg launch mass
- AMSAT Phase 3-C (HEO, OSCAR-13) on Ariane 401 in 1988, 140 kg (including propellant)
- AMSAT Phase 3-D (HEO, OSCAR-40) on Ariane 507 in 2000 with 650 kg launch mass
- AMSAT Phase 4-A (GEO, OSCAR-100) hosted payload on Es'hail-2 satellite launched in November 2018 on a Falcon 9 rocket. Narrow and Wideband bent-pipe Transponder with S-Band Uplink and X-Band (Ku) Downlink for voice, data and DVB-S2

With the help of a world-wide community of amateur radio operators (Hams), new communications and other technologies have been evaluated and further developed. This community is also a highly valuable resource for monitoring and receiving satellite telemetry data.

AMSAT-DL is operating a 20-Meter Antenna at the Bochum Observatory (Sternwarte Bochum) and achieved some notable space results from there, including ccontinuous 24/7 reception of the STEREO

A/B space weather beacon and forward to NOAA, reception of various satellites in MARS orbit, Venus echoes, Voyager-1 reception and support for other projects.

In 2010 the DLR and AMSAT-DL in cooperation performed a Concept Study for a Moon and Mars satellite (DLR-AMSAT P5) which was also presented to the German government. Part of this study can be re-used and therefore is attached to this proposal. It also underlines our capabilities and empathy for space related projects.

Why AMSAT on the Lunar Lander

Our LunaART communication platform would have several benefits to ESA and partners. It would not only create a sustainable base for public and educational outreach (including ESERO participation), it would also provide a "back-up" or secondary communications facility in case of "emergency" or provide independent access for University groups to their experiments on-board the Lunar Lander, in particular without interfering with the ESA infrastructure during busy or idle times. The Bochum 20-Meter Antenna could be used for higher data rates, while even amateur radio operators (and schools) will be able to receive lower data rates, even 2-way communication using the coherent transponder would be possible for communication and science experiments. The LunaART – Luna Amateur Radio Transponder – and its payloads will stimulate multilateral cooperation with school, ESERO and STEM organizations and international AMSAT organizations. We expect that multiple groups especially in Europe will contribute to LunaART with AMSAT-DL taking the lead. Such a challenging project will certainly motivate especially the next generation to achieve personal goals in education, science, engineering and beyond.

Description of the AMSAT-DL payload:

This payload shall feature:

1. TTC/TM digital link on amateur radio frequencies
    - Uplink: S-Band, 2400 MHz
    - Downlink: X-Band (Ku) on 10.45 GHz
    - Data rate up to 100 Kbit/s (or more)
    - Contents: must follow ITU regulations (open source data format), but could include data from imaging cameras, telemetry and science data from Student/University and other payloads.

2. A coherent transponder for 2-way communications on amateur radio frequencies
    - Bent-pipe linear transponder to allow all sorts of communications experiments with smaller earth stations, including ranging.
    - Uplink: S-Band, 2400 MHz
    - Downlink: X-Band (Ku) on 10.45 GHz
    - Bandwidth of several 100 kHz to allow multiple simultaneous operators

2. VHF (145 MHz) and UHF (435 MHz) transponder and Low Range Communication (Proximity, LoRA and other protocols).

3. Bi-directional link to the Amateur Radio (AREx) station on the Lunar Orbital Platform-Gateway.

4. Radio Science beacons with exceptionally low power only connected to Solar Cells and/or battery which could also provide "I'm alive" health information. For example, voltage and temperature coded into a simple "Morse code" beacon and/or employing advanced weak signal modulation and coding schemes.

AMSAT-DL would develop and build the hard- and software to be integrated into the Lander (space segment) as well as provide the ground station support from the 20-Meter Antenna at AMSAT-DL's HQ in Bochum.

We also envision to develop smaller ground station (~1m dish) to support other groups, Schools and Universities as part of ESERO and even ordinary ham radio operators to receive signals from the Lunar Lander for public demonstrations. Universities would get direct access to their experiments on-board the lander through their own licensed "Club Stations" and the LunART Communications Platform. We believe this "direct receiving/transmitting" from and to the Moon would also create a huge enthusiasm in participating groups.

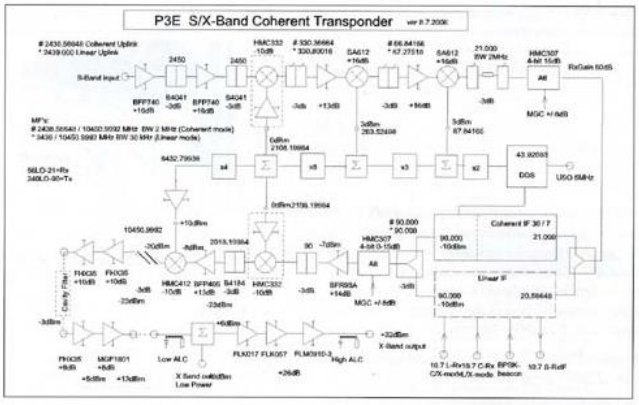
Thus, the AMSAT-DL LunART communications platform should help many of the experiments and could offload the day to day communications load from the ESA ground station. We envision to implement various up- and downlink data-rates to tailor the necessary bandwidth to the needs of the experiments while optimizing the link budget to the allow also smaller ground station to be included in the communication. The 20-Meter dish in Bochum would also allow a high speed / high bandwidth transfer of data from the experiments including high resolution pictures and/or videos.

<u>Communication payload:</u>

The communications payload would also support various scientific and educational experiments for ESERO and STEM organizations such as:

- Ranging experiment allowing to determine various orbital parameters of the moon
- A 50 – 100 kHz wide analogue bent pipe transponder would allow worldwide communications between schools and ESERO and STEM organizations using worldwide coordinated and allocated amateur radio frequencies. In many countries such as Germany educational licenses can be easily obtained where the students can operate the ground station supervised by licensed ham radio operators (similar like the ARISS school contacts with the international space station ISS).
- This transponder would also be an ideal platform to develop new transmission schemes with novel modulation and coding techniques optimizes for long distance communications with the corresponding high latency (long delays) as well as time and frequency dependent spreading of the signals e.g. by libration effects. This would provide essential knowledge in preparation of a future MARS mission.
- Transmission of still or slow motion (SSTV) pictures and video signals to the schools from cameras attached to the lander monitoring the moon surface and perhaps the earth in the

background would be ideal stimuli for getting school kids (ESERO projects) and STEM organizations further interested in space.



Beacon payload:

In addition to the 2-way communications platform AMSAT-DL also envisions to integrate radio science beacon transmitters into their payload. These low power beacons will transmit on various frequencies from VHF (145 MHz) to SHF (up to 24GHz or even 47 GHz) and provide to the ESERO and STEM organizations as well as the worldwide amateur radio community various possibilities for scientific measurements, such as:

- Investigations of frequency dependent phenomena like attenuation, frequency dispersion, polarization rotation, libration effects, doppler shifts etc.
- Further development of radio receiver technologies such as SDRs (software defined radios) and weak signal digital modulation schemes (such as JT65 and QRA64) to receive and decode the weak beacon signals.
- Alignment and optimization of smaller ground stations in schools and ESERO and STEM organizations using the well-defined and very frequency stable beacon signals.

Link to Lunar Orbital Platform-Gateway (AREx):

The Lunar Orbital Platform-Gateway (AREx) could be used as a relay link. The worldwide AREx group is currently developing ideas and first designs for the planned payloads. Various scenarios are possible, including VHF/UHF proximity and other protocols. This relay link can support both, bent-pipe and store-and-forward methods. AMSAT-DL has experience in both technologies with their implementations having been successfully used on several previous satellites.

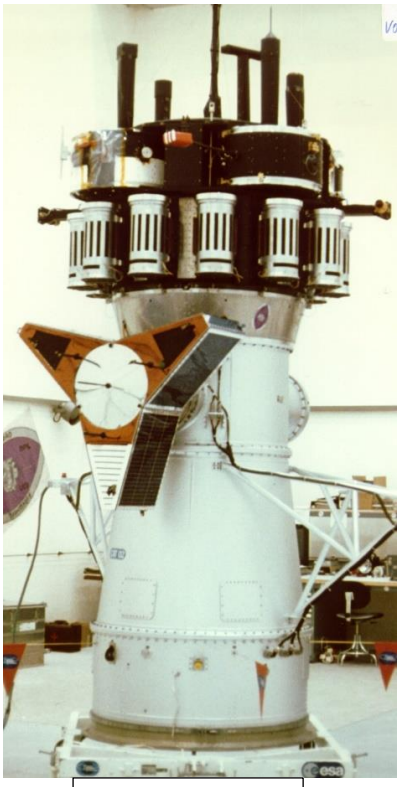
Links:

- ESA Deep Space Gateway: https://amsat-dl.org/esa-deep-space-gateway/
- Bochum Observatory, 20 Meter Antenna: https://amsat-dl.org/20-meter-antenna/

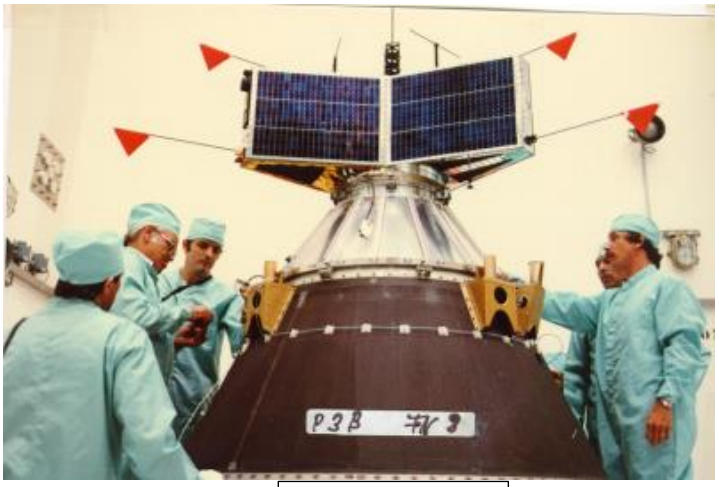
AMSAT-Deutschland, Blankensteiner Strasse 200 A, D-44797 Bochum, Germany

Mail: office@amsat-dl.org

Pictures say more than word…



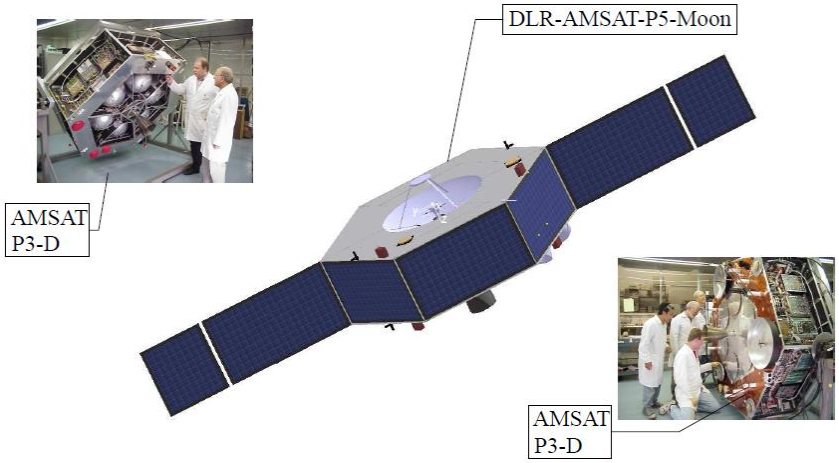
AMSAT P3-A



AMSAT P3-B

AMSAT P3-C

AMSAT P3-D



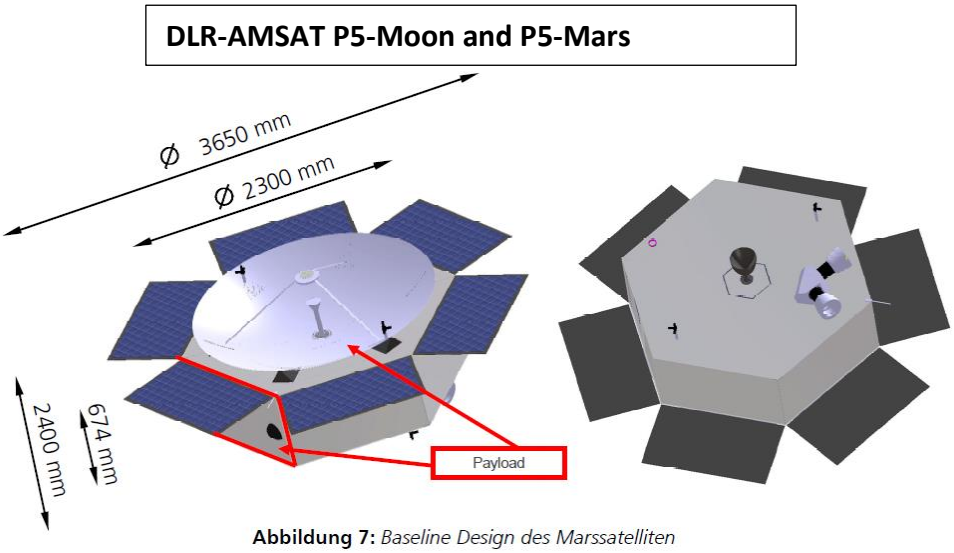
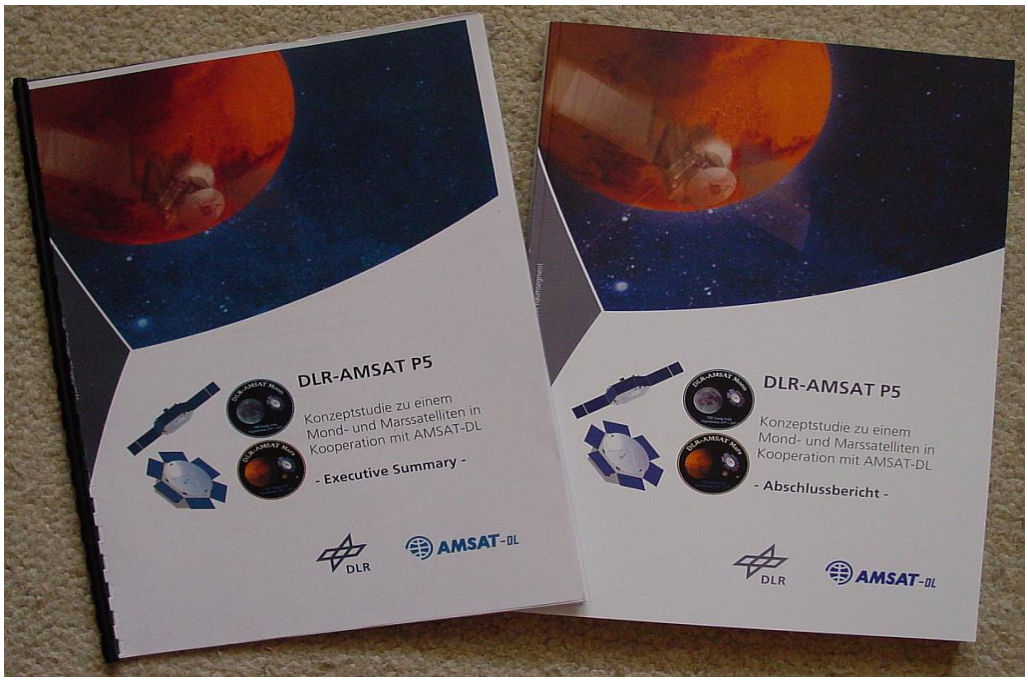


Abbildung 7: *Baseline Design des Marssatelliten*



20-Meter-Antenna in Radom, Bochum Observatory

AMSAT QO-100 Groundstation