NEW MOBILE EUROLAUNCH COMMAND, -TRACKING- A. DATA ACQUISITION STATION

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1 OBJECTIVES

1.1 Legend

Major investments into TT&C equipment happened already long time ago. Spare parts and service for all major components of the existing stations are not available anymore due to age of equipment and changes of technology. Therefore the need of a new investment in this field was initiated.

Last major investments:

Mobile TM-Station	1970
Mobile multi purpose station	1976
Receivers / Combiners	1987/1988
Antenna / Controller	1990

1.2 Market

The market of such a new TT&C station will cover satellite missions for earth observation, first acquisition at remote areas, worldwide programs for atmosphere research including sounding rocket and high altitude / long duration balloon projects, airplane testing, launch- and re-entry mission support.

Potential customers are:

- **Governmental Organizations**
  - Military
    Equipment testing (airplane, UAV …)
  - Public authorities
    Environment control (e.g. earth observation from none explored areas) and support of national and international research programs
- **Public Funded Organizations**
  - National space agencies (DLR, CNES, NASA, CTA)
    Various programs (reentry research, micro gravity research, student programs, satellite first acquisition)
  - European Space agency
    Various programs (micro gravity research, atmospheric research, earth observation …)
  - Universities
    Various programs (atmospheric research, earth observation, long duration flights, re-entry…)
- **Commercial Organizations**
  - Industry
    Industrial research programs (EADS, Astrium, OHB, SSC …)
  - Consulting companies (LEOPS, earth observation, tourism …)

1.3 Analysis

To be prepared for existing and new challenges in the field of aerospace activities, it is a necessity to reinvest in Ground Support Equipment at DLR. One urgent need for the future will be a highly flexible multipurpose mobile command, tracking and data receiving station.

- **High Mobility**

The need of high mobility has to be the basic design driver. Transport and set up of the station should be fast and easy with as less additional services as possible. Standardization of equipment size, packed and unpacked is elementary.

- **Automation**

The station has to be designed to support automation during preparation and the operation itself. The required operational effort will be reduced in comparison to today's standard.

- **Independency**

The design of a new station has to be based on the wish of high independency in the selection of location and also in the way of operation.

- **Flexibility**

The design has to consider the need of high flexibility in the field of possible applications. Mission based setup of the station should be easy and fast. The handling and setup has to be quickly adaptable to new incoming tasks.

1.4 Major specification

The Major field of operation is sounding rocket, aeroplane, LEOP satellite and stratospheric balloon missions.

The following points are important design drivers for this station.

- 20" standard size containers, expand-/ extendable and stackable
- Local / Diesel power input < 25kVA
- Air-condition from -40°C to +60°C minimum
- Antenna dish size ≤ 4.5m, separable
- S-Band Up- and Down Link
- Monopulse Auto tracking capability
- Sep. acquisition aid system
- Station G/T > 13dB
- RF-Transmitter Power ≤100W
- Integrated test equipment
  - Spectrum analysis

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- RF-Power meter
- Bore sight
- …

• Various external Interfaces

- Preprocessing
- Communication
- Timing
- LAN
- …

• Data handling

- Preprocessing
- Quick Look analysis
- Compression/Decompression
- Storage
- …

2 END TO END DESCRIPTION

2.1 Mission management

The procedure how to organize and realize projects with mobile stations is already well known and practiced since many years within MORABA as we have launched and tracked already hundreds of rockets and balloons during the last decades.
Major steps are:

- Campaign Planning
- Team organization
- Transport
- Mission
- Analysis and Reports

2.2 Mission Scenario

The mission starts with arrival of staff and equipment at the launch site. After placing the shelters at the right location and leveling them the built up of the station can start. Unpacking of the antenna flat and extension of the operational container are the next tasks. Power and communication can now be connected and the internal integration of the station can now be done. As soon as the antenna is integrated and connected first tests with the RF- system are on the schedule.
The fast acquisition tracking system can now be placed, assembled and connected close to the station in viewing direction to the launcher. The synchronization of looking angles is very important. Tests can be done with known radiating satellites, airplanes and bore site.
After readiness of station preparation final system tests verify operational functionality of the complete station. This is documented in a flight readiness report.

2.3 Link Calculation

To define important specification parameters some calculations according the link budget of the system have been done. Results of these calculations are direct inputs for the station specification list.

Constants

Speed of light m/ss $c := 2.99792458 \cdot 10^{8}$

Earth equatorial radius m $Re := 6378136$

Down - Link Frequency MHz $f := 2300$

$$\lambda := \frac{c}{f \cdot 10^{6}} \qquad \lambda = 0.13$$

Ground station - PERFORMANCE

Efficiency ground antenna $\eta := 0.45$

Diameter ground antenna m $D := 4.3$

$$\Theta := \frac{21}{f \cdot 10^{-3} \cdot D}$$

Beam size ground antenna deg

$\Theta = 2.123$

Transmitting pointing offs deg $Er := 0.1$

$$L\theta r := -12 \left(\frac{Er}{\Theta} \right)^{2}$$

Reduction of peak dB

$$Gpeak := \pi^{2} \cdot D^{2} \cdot \frac{\eta}{\lambda^{2}}$$

Ground station Antenna Gain (peak) dB

$Grpeak := 10 \cdot \log(Gpeak)$

Ground station Antenna Gain (eff.) dB

$Greff := Grpeak + L\theta r$ $\qquad Greff = 36.816$

System temperature °K $Ts := 150$

$Tsys := 10 \cdot \log(Ts)$

System noise db-K $Tsys = 21.761$

Ground Station G/T dB/K $GrT := Greff - Tsys$

$GrT = 15.055$

Ground station - UPLINK

Ground Station Output Power W $P := 100$

$GSOP := 10 \cdot \log(P)$

dBW $GSOP = 20$

Ground Station Feed Loss dB $GSFL := 2.0$

Ground Station Cable Loss dB $GSCL := 2.8$

Ground Station Antenna Gain dBi $Greff = 36.816$

Ground Station EIRP dBW

$EIRP := GSOP - GSCL - GSFL + Greff$

$EIRP = 52.016$

2.4 Requirements and Constraints

From the above mentioned facts the following important requirements and constraints are:

- Service of data reception and commanding
  This new station should have the capability to receive data and send commands to a moving object through a bi-directional radio connection.
- High mobility
  - Flexible transportation
  - The station should be transportable by, truck, train, ship and airplane.
  - Fast and easy assembly and disassembly
  - The station should be set up and packed within a few days by a minimum requirement of personnel.
- Packing size
  The packed size of the equipment should not exceed the volume of two standard 20" feet containers. All required equipment will be placed into these shelters.
- High adaptability
  The complete station should be adaptable to various mission goals as well as local circumstances. This adaptation should be easy, fast and cost effective.
- Minimal operational costs
  The operational costs should be minimized by reducing the necessary number of operating personnel and the extended use of remote control and support capability.
- S-Band Up and Down Link
  The use of a well known frequency band for both commanding and receiving opens a wide market and limits investment costs as well as equipment size.
- Reliable service conditions
  One important goal for realization should be reliable service conditions. The design of the station should take care of the planned operation period. Equipment with long service support is preferable. Due to increased export control problems, European products should be preferred whenever possible.

2.5 Elements

The station can be segmented into the following logical parts:

- Container and Electronic
- One 20" container will house all the required electric equipment that is necessary for operation. Also the operational personnel will be there during a mission.
- Pedestal and Antenna
- The second 20" container will house most of the equipment during transportation. During operation the pedestal with the antenna will be mounted on this flat.
- Interfaces
- For communication, data distribution and remote control, several interfaces and connections are required. Most of them are standard with a possibility to adapt to local needs if necessary.

3 STATION DESIGN

3.1 TT&C Antenna Specification

- A fully mobile S- band monopulse tracking antenna system.
- S- band command and receiving capability in parallel.
- A separate acquisition aid antenna with a 1.5m dish and an own tracking system for fast target acquisition as well as wide angle tracking capability.
- Polarization diversity for good signal quality even under extreme radiation conditions.
- Container flat mounted pedestal with assembly/disassembly devices for easy transportation and installation.
- A system pointing accuracy with main beam antenna ≤0.1°.
- The electronic equipment shall be placed in an acclimatized 20" container with shock mounted rack units.
- Environmental requirements are salt, pollutants, contaminants as uncounted in coastal, industrial, arctic and tropical areas.

Main Antenna:

Antenna Type:	~4m - meter parabolic reflector, separable, GFK/Carbon
f/D:	0.38 – 0.42
Feed System:	5 - element prime focus
Polarisation:	simultaneous RHCP and LHCP
Down Link Frequency Range:	S - Band ~2200 - ~2400 MHz
Beam width prime system:	S - Band ~2.5°
Antenna gain:	S - Band >36 dBi
Attenuation:	Additional ~40 dB LNA bypass switch
Sidelobes	> 20 dBp
G/T:	S - Band >13 dB/°K

Telecommand:

Polarisation:	switchable RHCP and LHCP
Up Link Frequency Range:	S - Band ~2000 - ~2100 MHz
EIRP	~52dBW
Beam width prime system:	S - Band ~2.5°
Antenna gain:	S - Band >36 dBi

Monopulse Tracking:

Scan Rate:	500 – 2000Hz
Side lobes:	20dB
Pointing accuracy	< 0.1° RMS
Temperature:	-40°C +60°C operational -50°C +70°C none operational
Monitoring	Temperature, Humidity

Pedestal:

Angular velocity:	>25 °/sec
Angular acceleration:	>25 °/sec²
Max. Wind vel.:	>80 Km/h operational >180 Km/h (none operational and stowed)
Rain:	Up to 100 mm/h
Mech. Accuracy: (backlash)	0.01°
Elevation:	-10° to + 190°
Azimuth:	± 410° or continuous
Temperature:	-40°C +60°C operational -50°C +70°C none operational
Power:	110/220 V 50-60 Hz
Monitoring:	Temperature, levelling

ACU:

Controller unit inside the container for operation

Abb 1) possible examples of ACU's

Features:

- PC Based Controller
- Wide Angle Viewing TFT Touch Screen
- Local Control via LAN, RS-232/422 or Fibre Optic
- Help Menu with ACU User Guide
- Password Protection for Sensitive Settings
- BIT (Built in Test) Features
- Robust Field Tested Software
- Analog & Digital Display of Antenna Position, Error Signals, and AGC
- Modes of Operation: Standby, Manual, Track / Acquire, Designate, Rate, Search and Slave
- USB, DVD drive
- Standard 19-in Rack Mount
- Expansion Bay for ISA or/and PCI Interfaces
- Utilizes Commercial Off-The-Shelf Hardware (COTS)
- Integrated hand wheels
- overhead tracking capability (plunge tracking mode)
- optional joystick control
- Integrated tracking receiver capability
- direct remote control
- service functions for moving the pedestal
- tbd.

Construction:

Mounted and operated on a 20" feet container flat.

Independently mount and dismountable.

Transportable on a 20" feet container.

mech./el. Level capability

Acquisition Antenna:	**(separate)**
Antenna Type:	~1.5m - meter parabolic reflector, separable, GFK/Carbon
Frequency Range:	S - Band ~2200 - ~2400 MHz
Beam width acquisition system:	S - Band ~6°
Polarisation:	simultaneous RHCP and LHCP
Antenna gain:	S - Band >28 dBi
Sidelobes (nominal	~ 12dBp
Operation	Independent from main system

3.2 Feed Design

For the antenna system a specific feed design is required. The feed must have the capability to autotrack a target in the single monopulse mode and in parallel to send commands toward the target. Additionally are two functions integrated, one to switch on/off the transmit capability and the other to switch on/off the preamplifiers to reduce the gain. The status of the switches are monitored, the temperature and humidity inside the feed are regulated to provide a stable operation condition.

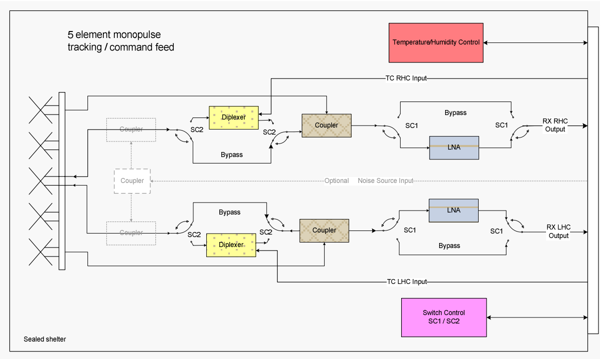
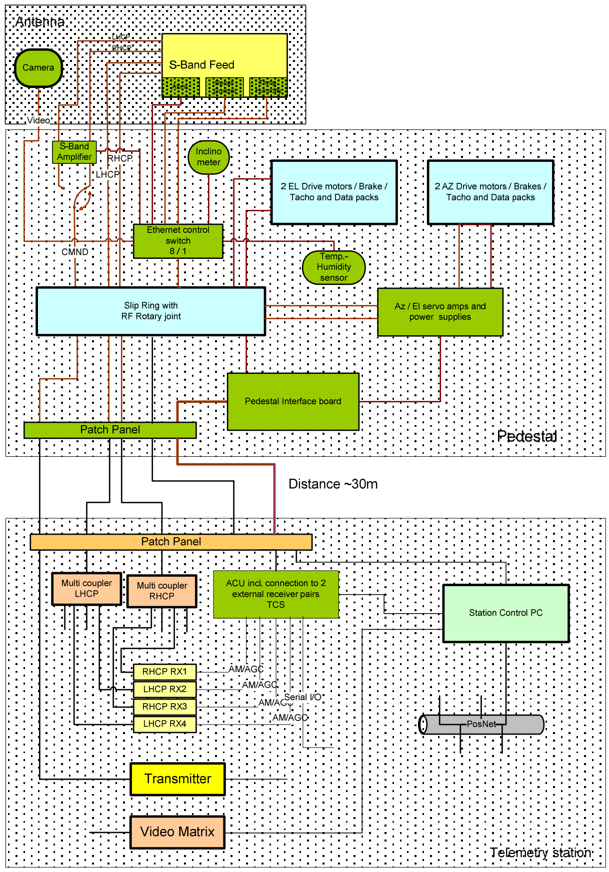


Abb 2) Feed design

3.3 Data flow

The schematic below show the main parts of cabling and data flow between the station and the antenna pedestal. The distance is designed to be about 30m. Pedestal and station have an interface patch panel for the external and internal cabling. Easy assembly and disassembly is provided here too. All monitoring and control data from pedestal to the station will be transferred via an Ethernet connection to the station PC. From there all operating and controlling happens. The digital video images from the integrated antenna camera are also distributed with this data connection. The video image from camera is then monitored inside the container to support the antenna operating with his information. All cables through the pedestal to the dish or to the elevation level pass a slip ring connection to avoid cable wrap through uncontrolled antenna movement. The antenna automatic control unit is divided into two parts. The main part is inside the operations container and the pedestal interface card is inside the pedestal. This card provides all required processes to operate the antenna in a predefined way.
Commanding data are created and modulated at the station and transferred via patch panels, cables and slip ring. After this the signal is divided and amplified for LHCP and RHCP transmission at the feed. RF downlink data are transferred direct from the feed via a rotary joint, patch panels and multi couplers to the receivers at the operating station. At the receiver the signal is demodulated and the output is preprocessed, archived and distributed to the customers for further processing.



Abbb 3) Dataflow overview

3.4 Graphical design of the station

The station consists of two major parts, the pedestal container and the operational station container. Both have the size of a 20" container. The antenna container is a fixed size container flat with mounting facility for the antenna and additional transport capability for further station equipment. With removable sides and an awning, it can be formed to a standard 20" container for easy transportation.
The Station container is also a basic 20" feet container for transportation but for operation he can be extended on both long sides. It houses the complete required equipment and the operational working area. The container is fully climatic controlled and has none breaking power selection between several input sources. (e.g. local power, UPS, diesel generator)
In case of use of an own diesel power generator it can be placed at one end of the antenna pedestal after set up of the complete antenna.

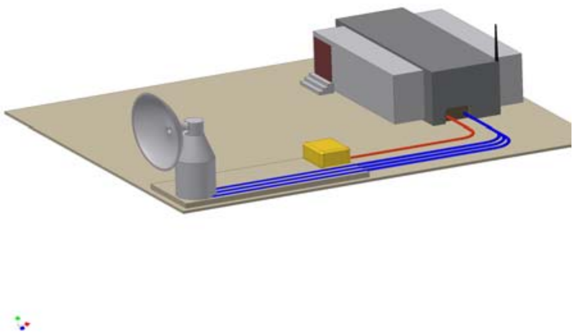


Abb 4) Principle Station buildup layout

The architecture of the built up operations container is shown below. The heavy and major parts are placed in the middle section and the extension elements are used for mobile equipment and the working environment. Also the main entrance is placed into one of the extension parts.
The Patch panels, the climate system and the power inputs are place on an extra area on one side of the container with access from inside and outside.
The climate system is designed to heat and cool the container with two separate and individual controllable paths. In addition the in cubed air is dried first a then mixed up again to the right volume. The floor contains an additional heater for arctic areas.

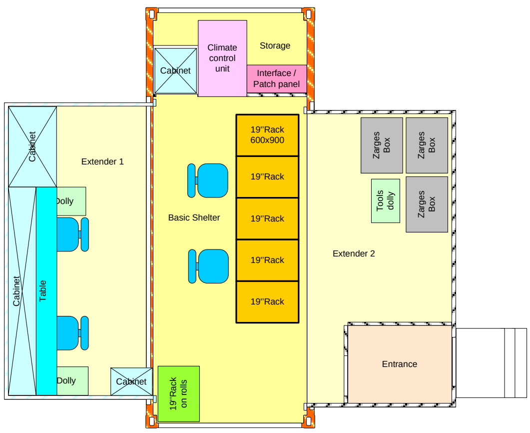


Abb 5) Basic design of shelters

The equipment for operation is mainly embedded in shock mounted 19" racks. The content of the racks is segmented horizontally into operational logical parts like tracking, recording, receiving, monitoring, processing and distributing. In vertical order the equipment with less control during operation is placed more on top or at the bottom of the rack while frequently used equipment is centred in the middle parts. On the walls of the extension of the container there are foldable table mounted which can be prepared for additional operating space. Laboratory storage room is also mounted here.

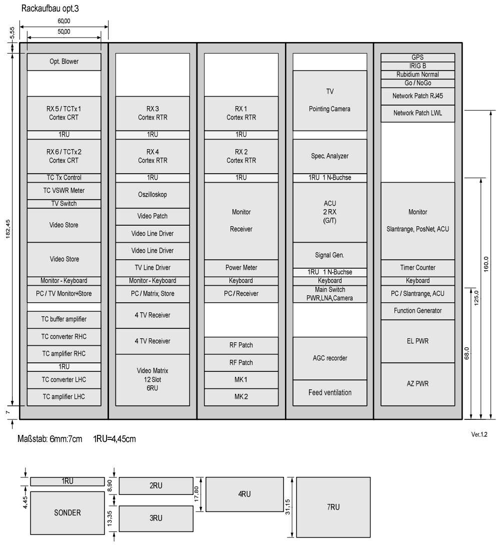


Abb 6) Design of rack units inside container

3.5 Guidance Network

The mobile station will be in most of the projects part of local safety or tracking data distribution network. The interface and message formats are individual on each rocket/balloon launch site. The adaption capability to all types of networks is mandatory for this station. This network service provides and supports the operator and other included facilities with actual target position and instantaneous impact point information. The station comprise an own internal target position information system. This system creates out of the slant range measurement and the pointing data information independent station specific trajectory information. All these data are created, displayed and distributed online.

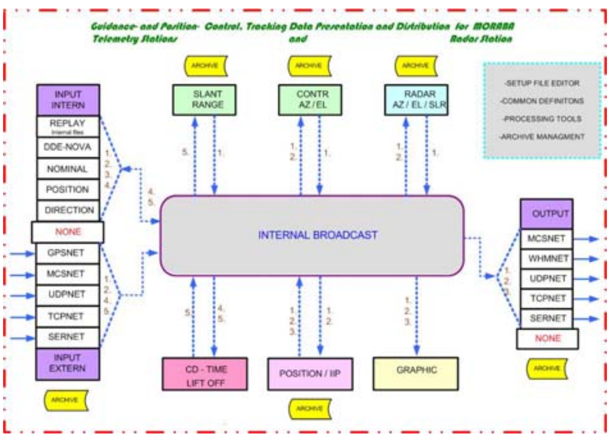


Abb 7) Tracking andPosition Data Network

3.6 Acquisition System

For acquisition of fast targets the main dish will be supported from a small completely independent tracking system. This ~1.5m dish system will slave the main system at the beginning of a launch and can take over backup or split target tracking functionality during the further flight operation.

4 INVESTMENTS

The investments for the built up of the station are divided and listed in a rough order.

4.1 Estimation of hard- and software cost for operational Station buildup

Here is a list of major components and parts required for the equipment container with average prices. Existing equipment is not planned to be used because of age and to expect none compatibility. It is also still in use with the actual operating stations.

Equipment container	250 K€
RF-Receiving Equipment (6 Receivers, 2 Multicoupler, RF patch-panel, cabling)	460 K€
RF-Command Equipment (2 Command encoder, 2 converter, 2 transmitter, cabling)	220 K€
TV-Video Equipment (2x video store, 3x line driver)	100 K€
PCM and Data processing Equipment	70 K€
Test, SLR, Timing and Network	80 K€
Matrixes, Switch panels, cabling, material	70 K€
Total	**~ 1250K€**

Here is the list of major parts required for the antenna container with average costs. There is existing equipment in our department which will be refurbished and used again. An available new 4.3m dish will also be integrated to this system. The combined commanding, receiving and auto tracking feed is a new development for the system and is created according specification.

Pedestal container	80 K€
Acquisition system	150 K€
Antenna pedestal refurbishment and new ACU	150 K€
TT&C Feed	170 K€
Total	**~ 550K€**

Complete System

Total	**~1800 K€**

4.2 Schedule of realization

The schedule of realization is in full progress. It is planned to have the station ready mid of 2010. The first operational mission will be the SHEFEX II campaign.

Final design	~2 months
Ordering and delivery of components	~10 months
Construction and integration	~ 3 months
Test and qualification	~ 3 months
Total	~18 months

4.3 Life Time

A first estimation of total costs shows that the investment can be recovered within 15 years.

Estimated operational period ~	15 years
Maximal utilization	150 days / year
Average utilization	60%/year
Expected revenues	230 K€ / year
Operational expenses	380 K€ /year

IN ADDITION EXISTING OLD STATIONS CAN BE SORTED OUT.

5 REFERENCES

- Existing manuals and Handbooks
- Product information of actual manufacturer within the RF- and Telemetry business.
- Various international telemetry standard documentation