Over the course of five decades, Tesat-Spacecom has developed in-depth expertise in manufacturing of payload equipment for communication satellites and has established itself as a clear European market leader. On its 60,000m² premises in Backnang, Germany, 1,200 employees develop, assemble, integrate, and test systems and equipment for telecommunication via satellite. To date, more than 700 space projects have been completed. The accumulated in-orbit lifetime heritage exceeds 250 million hours.

Our product offerings encompass highly reliable equipment as for example the travelling wave tube amplifiers, multiplexers, waveguide switches, and modulators, which along with complete systems are delivered to all leading satellite manufacturers worldwide.

Therefore, we offer the complete communication technology necessary to disseminate television signals via satellite to each household on ground. More than half of all communication satellites in orbit operate with Tesat equipment on board. The future global communication infrastructure has to support security-related real time applications with ubiquitous coverage. This will only be viable with most advanced communication systems operating in space.

Tesat has successfully developed the key element for this space infrastructure, the optical broadband Laser Communication Terminal (LCT). Using lasers, such terminals can transmit data and imagery between satellites and from satellites to ground at unprecedented data rates. We at Tesat have demonstrated for the first time the operational capabilities of such broadband LCTs in space. Given our competitive position in the commercial satellite market and our top quality standards, Tesat products are today the first choice for various satellite-based systems operated by several governments worldwide for security and defense related applications.

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**Starting point is the transformation of mission or Payload requirements into subsystem and equipment specifications as well as design and layout optimization with respect to performance, energy efficiency, geometry, mass and further customer-specific requirements. We take advantage of exceptional knowledge and heritage as well as cutting-edge technologies on equipment level all available at the Tesat site. With this, we enable system designs that are optimized to fulfill the need of our customers. Our focus is on customer specific solutions, with priority on small and medium sized communication payloads including Hybrid Optical/RF Relay payloads, making Tesat a predestinated hosted Payload supplier.**

Our customers benefit from:
- Our comprehensive product portfolio and equipment know-how
- Our extensive expertise with regard to system engineering, design, analysis, simulation, integration and test
- The in-house Parts Agency
- Our well-established procurement management based on long-term customer-supplier-relationships
- The application of state-of-the-art technologies and processes
- The multitude of available engineering and design tools covering electrical, mechanical, thermal and radiation aspects.

**Payload Layout**

Includes reflector antennas and direct radiating array antenna.

*Activities covered under Small GEO ESA program*
2 THE PRODUCTS
DOWNLINK SUBSYSTEMS - REPEATERS & PAYLOADS

PRODUCT SCOPE

The product scope of Communication Systems comprises two key products – the Data Downlink Subsystem family and the Repeaters/Payloads including the unique configuration of a Hybrid Relay Payload featuring Laser ISL (Inter-Satellite Link) with multi-channel Ka-Band downlink.

REPEATERS & PAYLOADS
for Telecommunication, all frequency ranges

DOWNLINK SUBSYSTEMS
for EO/Science X-/Ka-Band QPSK/B-PSK
Next Generation: 16/32/64-APSK
Communication Systems of Tesat offers a variety of Data Downlink Subsystems to satisfy these requirements. The below picture illustrates the two basic principles for data transmission from LEO to GEO:

- **Direct data transmission between the LEO satellite and the ground station in X-Band or Ka-Band**
- **Data transmission via data relay satellites based on RF or Optical Inter-Satellite-Links (ISL) between LEO and GEO and transmission of data from GEO to LEO in Ka-Band (multi-channel configuration possible for higher data rates).**

Earth observation is essential for improving our understanding of the planet’s environment as well as its past and future. Based on sophisticated sensor designs and applications the amount of collected data is increasing and the demand for a transmission at higher data rates is an immediate consequence.

**Earth observation (EO) satellite downlinks**

**DATA DOWNLINK SUBSYSTEMS**

Tesat features a long and very successful heritage for Downlink Subsystems since more than 20 years starting with Envisat. Based on cutting-edge technology, we provide Downlink Subsystem concepts to fulfill the growing data rate requirements.

Tesat is a one-stop-shop that includes all engineering services (RF, layout, interfaces, reliability), procurement, project management, subsystem assembly, integration and test in Backnang. In addition, support for system level activities can be offered and test systems can be delivered, if requested by the customer.

Downlink Subsystems for earth observation and military missions are available in X-Band (8.8-8.4 GHz) with QPSK and B-PSK modulation and Ka-Band (25.5-27 GHz) with QPSK modulation. The products are designed for LEO as well as GEO applications with a lifetime of up to 15 years.

**Typical contact times:**
- LEO - GS: 10 min
- LEO - GEO - GS: 45 min

### Mass Memory

Tesat products procurable products

**Diagram:**
- **Antenna**
- **Filter**
- **Switch**
- **Amplifier**
- **Modulator**
- **Instrument (Camera, Sensor)**

**Table:**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Mass Memory</th>
<th>Mass Memory</th>
</tr>
</thead>
</table>
**X-BAND / KA-BAND DOWNLINK SUBSYSTEMS**

Examples for achievable data rates depending on modulation and coding schemes as well as the utilized frequency band:

(Data rates can be doubled with a dual channel architecture):

<table>
<thead>
<tr>
<th>Modulation Scheme</th>
<th>Coding Scheme</th>
<th>Band</th>
<th>Max. User Data Rate per Channel (Mbit/sec)</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK Hardkeyed</td>
<td>None</td>
<td>X</td>
<td>350</td>
<td>Available</td>
</tr>
<tr>
<td>8-PSK</td>
<td>4D-TCM, r=5/6</td>
<td>X</td>
<td>500</td>
<td>Available</td>
</tr>
<tr>
<td>64-APSK</td>
<td>SCCC, r=0.9</td>
<td>X</td>
<td>1,200</td>
<td>under development, available 2017</td>
</tr>
<tr>
<td>QPSK Hardkeyed</td>
<td>None</td>
<td>Ka</td>
<td>600</td>
<td>Available</td>
</tr>
<tr>
<td>32-APSK</td>
<td>SCCC, r=0.82</td>
<td>Ka</td>
<td>2,000</td>
<td>under development, available 2017</td>
</tr>
</tbody>
</table>

**NEXT GENERATION DOWNLINK SUBSYSTEMS-CONCEPT**

Tesat currently develops a next generation data Downlink Subsystem to strengthen its position as the leading supplier for high data rate Downlink Subsystems – as future EO projects and relay missions will require:

- High flexibility in order to cope with changing needs respecting data rates and link conditions
- Digital predistortion for linearization based on post-TWT feedback loop
- Considerably higher data rates
- Bandwidth-efficient modulation schemes (16/32/64-APSK)
- Powerful coding schemes (SCCC)
- Digital predistortion allowing a linearisation of the high power amplifier

The block diagram below shows an example for a next generation X-Band Downlink Subsystem with a data rate up to 2,400 Mbit/sec (1,200 Mbit/sec per channel) with 64-APSK modulation and powerful SCCC coding.
Tests were performed including a flight TWT at 26.7 GHz for full symbol rate of 500 Mbps as shown in the figure. In order to gain representative end-to-end performance results, a receiver prototype was used. To ensure representative test conditions, a noise source was used to simulate the RF link conditions. Measured Bit Error Performance up to 64-APSK shows very low implementation loss and thus demonstrates efficiency of digital predistortion.

**Benefits of Optical Communication**
- High throughput allows transfer of high data volumes
- High immunity against jamming and lowest intercept probability due to narrow beam width
- No ITU frequency regulations in the optical spectrum

**Benefits of Relay Payloads**
- Beam hopping to serve a fleet of LEOs
- Near real time data transmission during LEO-GEO sightline
- Significant enlarged time-window for data transmission
The EDRA Relay Payload (Fig. 1) includes both an optical/laser and an RF/Ka-Band Inter-Satellite-Link. The payload was fully designed at Tesat. The design activities included also the support for the end-to-end System definition.

The EDRA Block Diagram (Fig. 2) shows the extensive functions performed by the Relay Payload.

**EDRS SUCCESS STORY**

On January, 29th 2016, the EDRS-A Payload hosted on Eutelsat 9B was successfully launched and in-orbit test activities were successfully concluded end of May 2016.

Future generations of Hybrid Relay Satellite payloads may include advanced features like:

- High-speed connection with small latency from ground to LEO via relay (enhanced forward)
- Power & bandwidth efficient transmission on the RF downlink by using advanced coding and high-order modulation schemes
- Optical GEO-GEO Interconnection capability. The Next Generation Relay Payloads will be equipped with multiple LCTs and sophisticated data processing enabling routing capabilities
- LEO-GEO communication extension with several Ka-Band Inter-Satellite Links to serve LEOs without LCTs
- Security/encryption for dedicated applications
- Future hybrid payloads will directly benefit from any evolution of the LCT

These advanced features will enable enhanced mission tasking and extend the service flexibility and adaptability.
Next Generation Hybrid Relay payloads will be able to serve multiple users and support multihop links together with further relay nodes. This will result in a global coverage of the relay service. Usage of data buffering could enable flexible link adaptation in order to achieve robustness against atmospheric effects. At the same time, the architecture employing new modulation and coding concepts will allow considerably higher data throughput.

An Advanced Mission Control Concept aims at a maximum of overall system autonomy and increased flexibility for the end user and for maximum security for end user data.

Laser Communication Terminal and the majority of the other key elements are Tesat products developed and manufactured on site.

Next Generation Hybrid Relay Payload configurations are currently being developed at Tesat.

**REPEATERS / PAYLOADS**

Tesat-Spacecom has been working in the field of Repeater/Payload programs for more than three decades. The first Repeater program for Tesat (formerly Telefunken) was the C-Band Repeater for Intelsat IV-F3 at the beginning of the 1970s. Our actual Payload programs are Hispasat AG1, EDRS-A/C and the Phase A / B Payload study for H2SAT.

Our aim is to be a solution provider for your success in satellite communication. We cover all aspects and tasks necessary for a successful payload project from project management, subcontractor and supply chain management, payload engineering, layout and interface engineering, quality assurance to assembly, integration and test (AIT) as well as in-orbit testing (IOT).

We benefit from lean management structures and short communication links within the company, close collaboration with the product line amplifier/Datalink/Laser/passive products and parts agency and service lines for optimized payload designs. We efficiently coordinate the AIT-phases on equipment, subsystem and system level in Backnang and at Prime facilities.

Our focus is on small and medium sized Communication Payloads including Hybrid Optical / RF Payloads. Additionally, we offer vast experience in implementing new technologies through in-orbit verification (IOV) missions, the design and implementation of hosted Payloads to our customers.
### TRANSPARENT PAYLOAD AND REPEATER PRODUCTS

Tesat-Spacecom has a uniquely wide product portfolio comprising all types of repeater equipment. Tesat has considerable heritage in designing, producing and testing large repeaters and payloads. We efficiently coordinate and perform the AIT-Phases on equipment level, subsystem and system level in Backnang and at prime facilities. Beyond that, we offer to our customers vast experience in implementing new technologies through in-orbit verification missions and the design and implementation of hosted Payloads.

<table>
<thead>
<tr>
<th>COMMS MODCS</th>
<th>Hispasat AG1</th>
<th>Heinrich Hertz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small S/L-Band Payload</td>
<td>Communication Satellite plus on-board processor and direct radiating array antenna</td>
<td>Communication Satellite with in-orbit-verification (IOV) Payload and MIL Payload</td>
</tr>
<tr>
<td>333 kg Mass</td>
<td>400 kg Mass</td>
<td>420 kg total Mass</td>
</tr>
<tr>
<td>174 W Payload Power</td>
<td>4,000 W Payload Power</td>
<td>3,500 W total Payload Power</td>
</tr>
<tr>
<td>S-Band Horn RX Antenna L-Band Horn TX Antenna</td>
<td>• 2 dual reflector Ku-Band TX/RX antennas</td>
<td>• 1 top deck Ka-Band direct radiating array antenna</td>
</tr>
<tr>
<td>• 1 fixed Ka-Band TX/RX top deck antenna</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-Band, S-Band</td>
<td>Ku-Band, Ka-Band</td>
<td>Ku-Band, Ka-Band</td>
</tr>
<tr>
<td>Dual channel (one transparent, one for downlink)</td>
<td>24 Ku-Band Channels</td>
<td>5 Ka-Band Channels</td>
</tr>
<tr>
<td></td>
<td>IOV: 8 channels</td>
<td>MIL: restricted</td>
</tr>
</tbody>
</table>
| POWER RANGES — MASS, POWER & CHANNELS

Our focus is on customer specific solutions, with priority on small and medium sized communication as well as hosted Payloads.

Tesat features extensive heritage and experience with small up to medium sized Payloads on a variety of platforms and with many different Satellite Primes. This makes Tesat an independent Payload & Equipment Supplier with outstanding know-how regarding customer requirements.

Tesat is a First Class Hosted Payload Supplier for Communication Payloads, Hybrid & RF Relay Payloads and IOV Payloads.
THE FACILITIES

ASSEMBLY, INTEGRATION, TEST.

For more than 30 years Tesat-Spacecom has been involved in AIT activities on Repeater and Payload level starting from the OTS Repeater (Orbital Test Satellite) to SATCOMb2 to the current Payload programs like Hispasat AG1 and EDRS.

The AIT area is fully equipped and staffed to perform complex assembly, integration and test operations on Downlink Subsystems and Repeaters from L-Band to V-Band.

The Integration Hall itself comprises a clean room (cl.8) area of approximately 500 m², of which ~250 m² have a height of ~10 m. The hoist unit in the integration hall is a crane with a load capacity of 2,000 kg SWL and a height of about 8 m. The air lock dimensions are 3.7 m x 4.6 m.

*Activities covered under Small GFO ESA program
The EMC-Chamber is a double shielded chamber in line with MIL-STD 461. The dimensions of the EMC-Chamber are 7.4 x 6.0 x 5.0 m (L x W x H) with a door size of 310 x 360 cm (W x H). All standard tests like RS/RE and CS/CE (Radiated and Conducted Susceptibility/Emission) can be performed with our test-equipment.

At Tesat-Spacecom, we have well-established capabilities to design, procure, calibrate, operate and deliver Test-Systems for test activities on Sub-system- and System-Level.
In the frame of the Flex INET/ONET development programs, Tesat is investigating flexible Payload configurations based on „analogue“ equipment technologies. Flexible MPMs with adjustable saturated output power are already part of our PM product portfolio. In the running H2SAT Payload Program (funded by DLR), an in-orbit-verification of such new technologies (with many innovations from German universities, research institutes and companies) is envisaged.