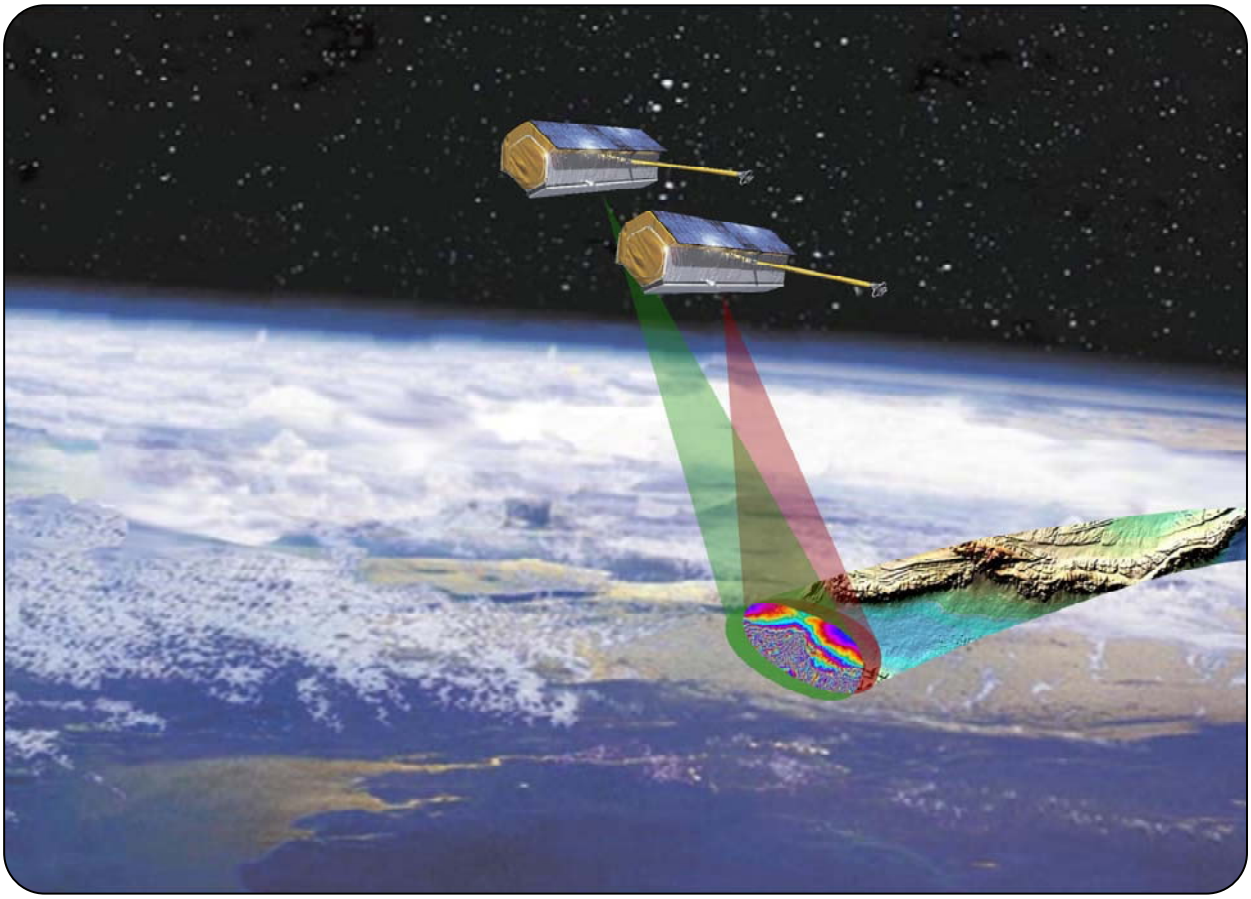
TanDEM - X

TerraSAR-X Add-on for Digital Elevation Measurements



Announcement of Opportunity

For Secondary Payload

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1 DESCRIPTION OF OPPORTUNITY

1.1 Introduction and Programmatic Context

In Germany Earth observation satellites like TerraSAR-X are being funded and build under a public-private partnership between the German Aerospace Center (DLR) and the space company EADS Astrium GmbH, Friedrichshafen.

By early 2006 the TerraSAR-X radar satellite will be launched with a Russian launcher in order to provide geo-information of new quality for at least 5 years from an altitude of 500 kilometers. DLR will be responsible for its scientific use while exclusive commercial marketing of the geo-information gathered will be carried out by Infoterra GmbH (Friedrichshafen), a wholly-owned subsidiary of EADS Astrium GmbH (hereafter “Astrium”) specializing in the collection and processing of air- and satellite-sourced data.

In continuation of this program a study is now being performed by Astrium for a second SAR satellite called TanDEM-X, which is intended to be launched in late 2008 to fly in a close tandem orbit configuration with TerraSAR-X, forming a huge radar interferometer.

TanDEM-X (**T**erraSAR-X **a**dd-o**n** for **D**igital **E**levation **M**easurement) has the goal of generating a global Digital Elevation Model (DEM) with an unprecedented capability of measuring terrain height with < 2 m accuracy during its formation flight with TerraSAR-X.

This second SAR Satellite TanDEM-X apart from minor adaptations will be a complete rebuilt of the TerraSAR-X, requiring almost no additional development, thus keeping the technical and schedule risk low.

The purpose of the TanDEM-X study, being finished by mid June 2005, is to primarily focus on the investigation of time and mission critical topics, the analysis of the formation flight and identification of respective modifications which may be necessary (if any). At the end of the study the prerequisites for binding cost estimates covering the project phases B, C/D and E will be available as basis for a formal proposal towards DLR.

It is expected that DLR will decide on the realization of TanDEM-X by the end of 2005.

In the frame of the above mentioned public-private partnership with DLR, Astrium has the right to choose a secondary payload for the TanDEM-X satellite for which a (preliminary) selection of candidates will also be performed within the current study.

Final selection of the secondary payload naturally can only be performed after the TanDEM-X proposal has been accepted by the DLR and a contract has been awarded to Astrium.

1.2 Opportunity for Secondary TanDEM-X Payload

With this document Astrium announces the opportunity for accommodating a secondary payload aboard the TanDEM-X spacecraft with the following parameters:

Possible location on TanDEM-X spacecraft	See Figure 1-1a to f
Mass • total • per single unit / component	 < 120 kg < 60 kg
Power Demand (average)	< 150 W
Power Distribution Interface • either Unregulated Bus • or converter to (preferred)	 42 V - 52 V 28 V +/-10 %
Telecommand Up-Link (in S-Band) • Data Rate • Modulation	 4 kbit/s BPSK
Telemetry Down-Link (S-Band) • Data Rate for scheduled ground contacts	 500 kbit/s
Data Storage Capability incl. HK (RAM)	1Gbit
Data Interface • MIL 1550 (preferred) • UART / RS422	

Table 1-1: Opportunity for Secondary Payload

Payloads to be addressed with this AO shall be self standing and independent units interfacing only with the satellite bus.

For this kind of payload, the flight opportunity offers a unique possibility in using the TanDEM-X spacecraft as a scientific platform.

Cost for the accommodation and the operation of the secondary payload will be borne by the proposer.

Astrium will request a flight opportunity fee of between 3 M€ and 5 M€ depending on the general complexity of handling the payload.

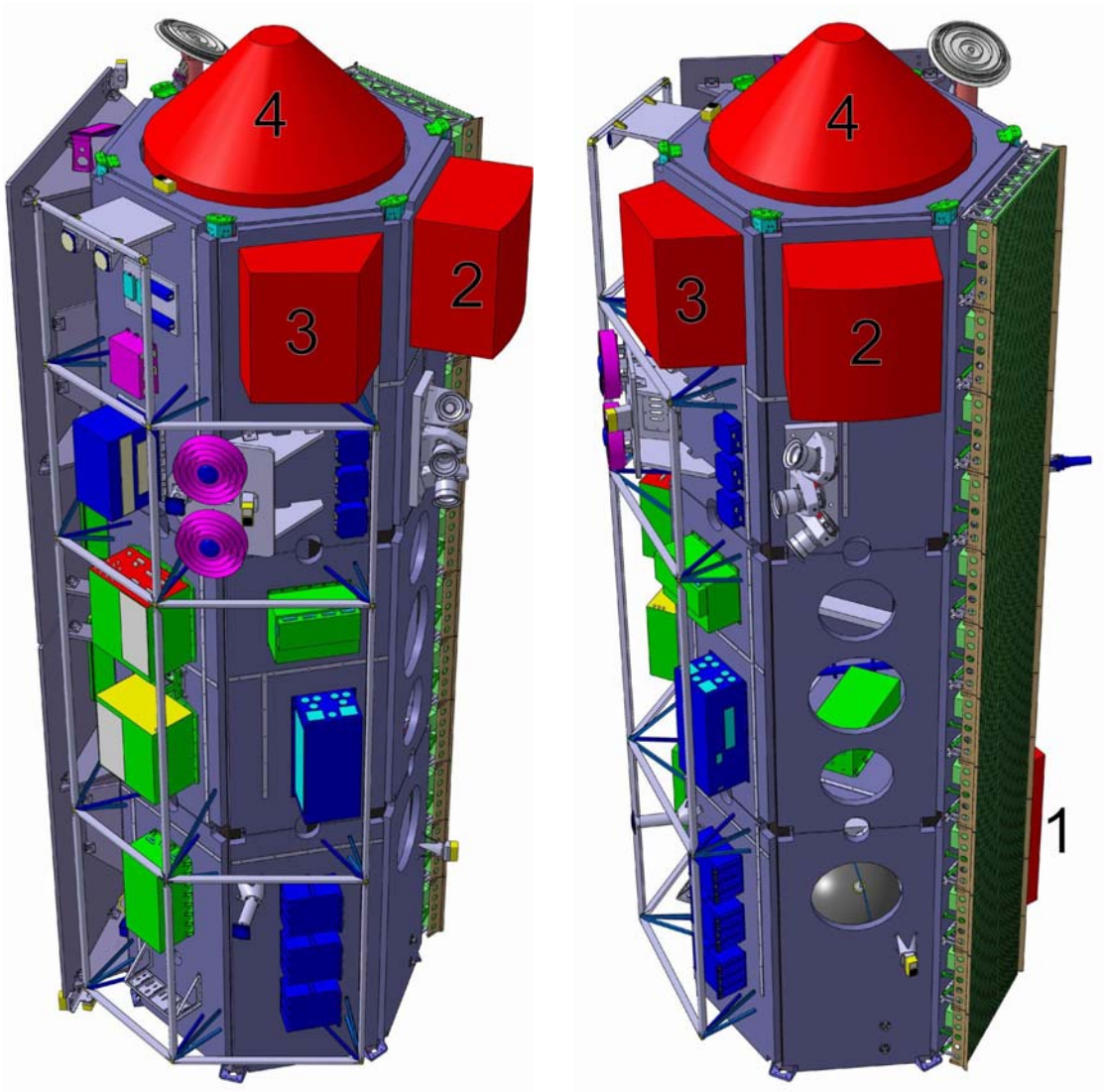

Figure 1-1a-b: Possible Accommodation Volumes of Secondary Payload

Red marked areas show available volume for secondary payload.

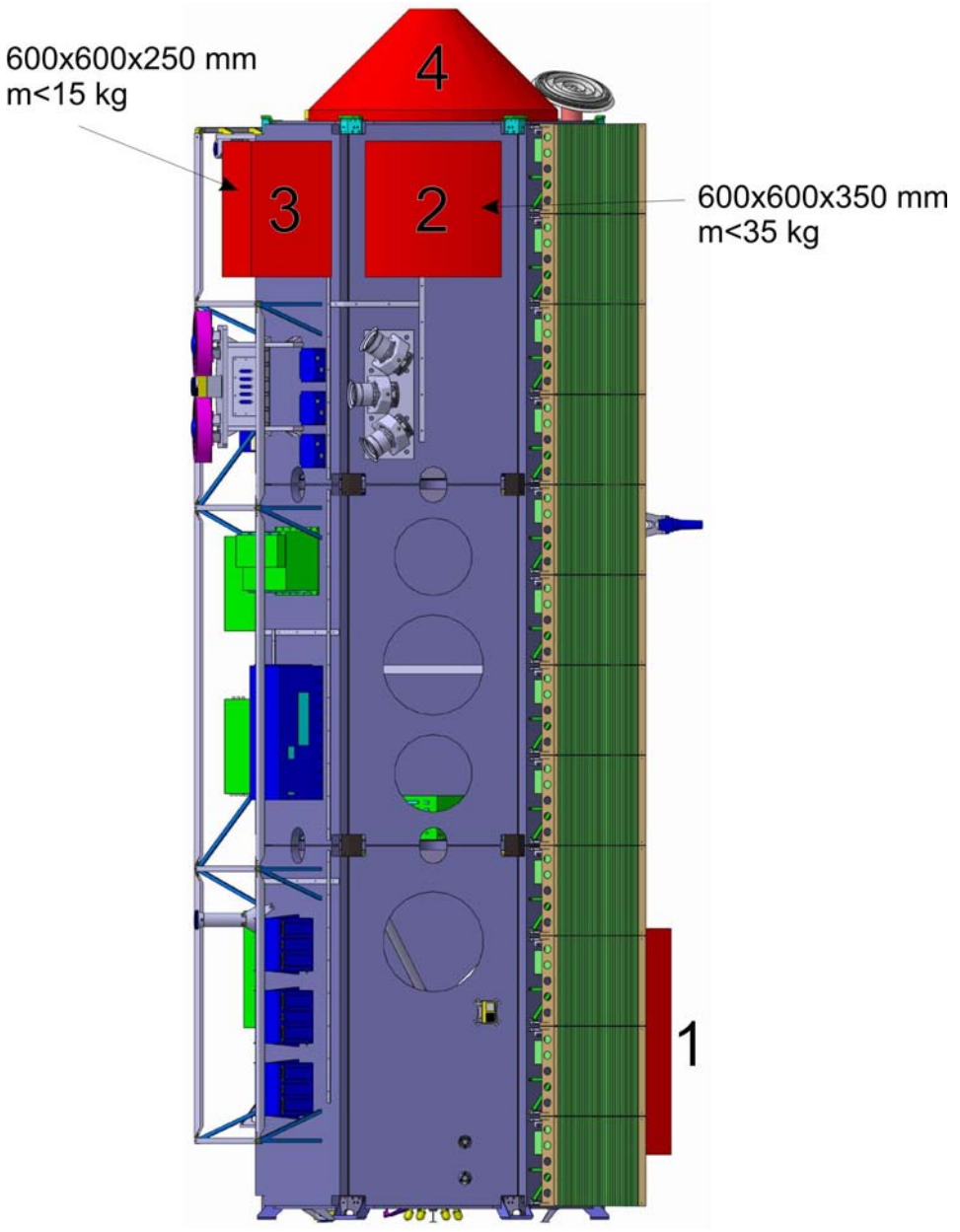

Figure 1-1c: Possible Accommodation Volumes of Secondary Payload

Red marked areas show available volume for secondary payload.

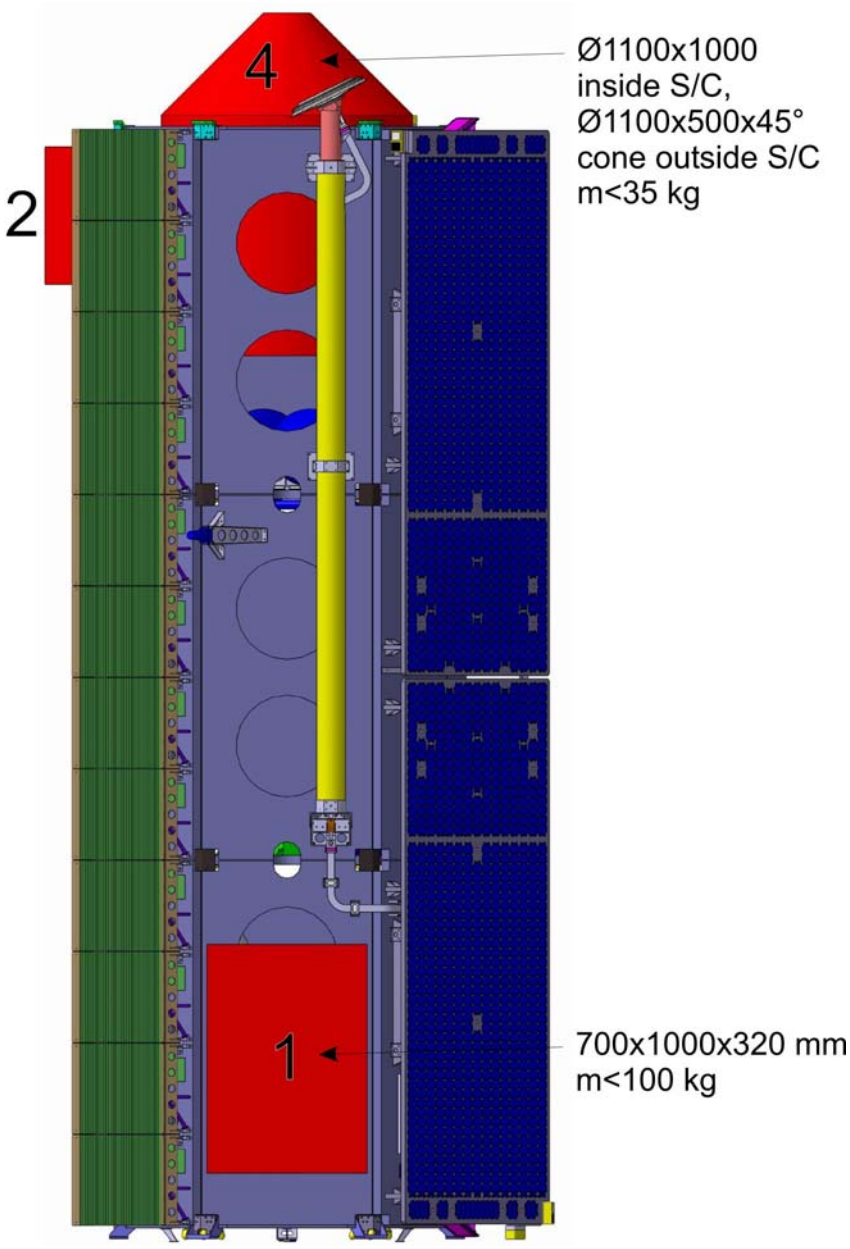

Figure 1-1d: Possible Accommodation Volumes of Secondary Payload

Red marked areas show available volume for secondary payload.

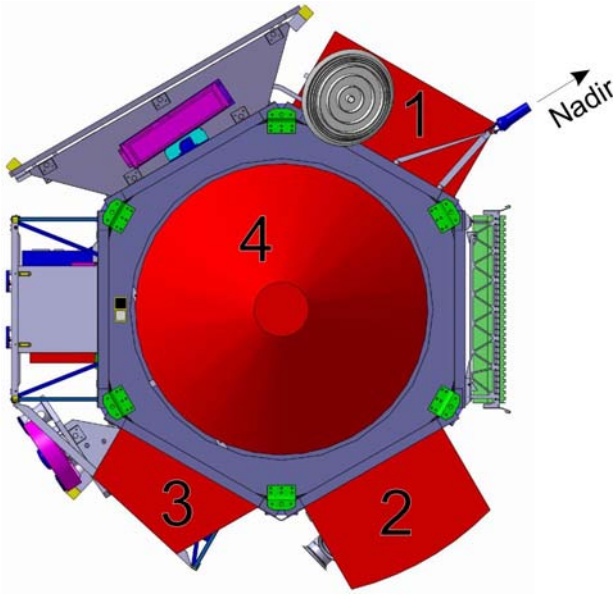

Figure 1-1e: Possible Accommodation Volumes of Secondary Payload

Red marked areas show available volume for secondary payload.

1.3 Two Step Proposal and Evaluation Process

In order to reduce the overall effort in preparing full proposals and with respect to the mission schedule, Astrium plans to conduct a shortened two-step evaluation process for this AO.

Proposers responding to this AO shall first submit a Notice of Intent (NOI) with emphasis on the planned instrumentation, technical maturity, measurement approach and some assessment of the mission's technical risk.

As a minimum, the following information will be requested for the NOI:

- A brief description of the proposed payload, its mission and demonstration of the financing concept
- A list of names, mailing address, phone number, and email address for the lead representatives from each organization included,
- A proposal on the launch fee.

Ratings will be determined for each NOI basing on programmatic significance, technical maturity and on the proposed launch fee. Based on the rating, Astrium will recommend whether or not a full proposal is worth to be submitted containing detailed information with respect to technics and management.

The full proposal shall enable Astrium to make a preliminary selection of the secondary payload as basis for a binding Phase B, C/D, E & F proposal towards DLR at the end of the TanDEM-X study phase.

The following information is required for the full proposal:

- A detailed description of the secondary payload, covering all aspects of section 2,
- the name, mailing address, phone number, and email address for the following:
    - Lead representative,
    - Official by title of the representative's organization who is authorized to commit
    - the organization,

Only payload proposals showing a complete mission scenario will be accepted.

As mentioned above this evaluation process is only preliminary, pending on the selection of TanDEM-X as a favourite DLR earth observation program.

NOIs and proposals shall be written in English.

1.4 Proposal Opportunity Period and Schedule

The opportunity for the shortened selection cycle shall be in accordance to the nominal schedule shown below:

Date of AO release	October 08, 2004
Notices of Intent (NOI) due	November 13, 2004
Release of Step-One Ratings	December 20, 2004
Full Proposals due	February 28, 2005
Announcement of preliminary proposal(s) selection	April 11, 2005
Preliminary Design Review	May, 2005
Final Selection of secondary P/L (pending on TanDEM-X contract award)	Late 2005

Table 1-2: Proposal Opportunity Schedule

2 PROGRAM CONSTRAINTS, GUIDELINES AND REQUIREMENTS

2.1 General Program Constraints

2.1.1 Schedule

With a TanDEM-X Phase B, C/D, E contract start in end 2005 a launch of TanDEM-X satellite can be achieved in late 2008, approximately 36 months after kick-off. The duration is determined by procurement lead time of S/C components. For the Space Segment basically no definition phase would be required and therefore three months after authorization to proceed, the procurement of S/C units can be initiated. The satellite will be designed for a 5 mission life time.

All proposed payloads shall be ready for integration with the satellite by end January 2007 at the latest.

2.1.2 Funding

The TanDEM-X Program represents an effort by German Aerospace Center DLR and Astrium to develop and implement a both scientifically and commercially oriented EO mission

in a public-private-partnership concept, indicating that both the public and private partners have found a compromise in making available a maximum amount of financial resources. To this end, additional funding for the secondary payload selected under this AO is not available.

The final proposal shall include a commitment by the proposer to contribute the payload and necessary services without additional funding from Astrium and the German Agency DLR.

2.2 Participation

Participation in the TanDEM-X Mission consists of the contribution of the instrument to the satellite and the mission.

The handling fee and the payload accommodation cost have to be funded to Astrium.

The effort related to mission operations, data processing, communications and mission science, etc. has to be identified, negotiated, and funded under a separate agreement.

The relationship between the TanDEM-X prime contractor Astrium and potential new industrial partners will be on a prime-/ subcontractor basis, controlled by a contract regulating all elements/tasks with respect to the hardware to be accommodated on the spacecraft. The resulting contract shall not impact the Astrium prime contract with DLR. The TanDEM-X mission aspects prevail over the mission aspects of the additional payload in case of conflict.

2.3 Technical Requirements

The AO proposals shall include all technical aspects of the investigation from concept definition, development through operations. The full proposal shall meet the requirements of the European Cooperation for Space Standardisation ECSS or equivalent standards.

The proposer shall demonstrate to Astrium. that the nominal operation of the TanDEM-X spacecraft and the primary instrument will not be affected by any failure of the secondary payload. Therefore, the proposed design of the additional payload shall be double failure tolerant against any failure propagation to the satellite.

2.4 Cost Requirements

Funding for secondary payload instrumentation by Astrium is not foreseen. Once selected, the proposer / Agency is primarily responsible to allocate the approved funds to meet cost-to-complete requirements of the mission. This also includes a contribution to the TanDEM-X system and launch costs of 3 to 5 M€, depending on the type of payload. Therefore, the proposer / Agency must demonstrate already for step 1 the allocation of available funds to avoid schedule delays and cost over-runs throughout the mission.

2.5 Management Requirements

According to section 2.2 the organization, industry or agency, supporting the selected proposal will have full responsibility and authority. This means that the responsibility for committed cost, schedule, performance, quality, reliability and safety requirements is not shared by Astrium as the TanDEM-X prime contractor. In addition, both Astrium and its Agency DLR will have the right to proceed without the AO partner in case of events jeopardizing costs and schedule of the TanDEM-X program.

To avoid such a situation the secondary payload proposer shall submit, at a minimum, monthly programmatic reports to Astrium that include significant accomplishments:

- the status of technical margins,
- mission risk identification,
- mitigation tracking and resolution
- the current schedule situation.

AO Unit level reviews such as listed below will be conducted by the secondary payload provider:

- Preliminary Design Review (PDR),
- Critical Design Review (CDR),
- Pre-Shipment Review(PSR),
- Integration Readiness Review (IRR).
- Flight Acceptance Review (FAR).

In order to assess the progress of the development of the secondary payload and to provide Astrium with necessary technical and programmatic insight, it is foreseen to conduct progress meetings on a 3 monthly basis.

It is desirable in the NOI but essential for the full proposal to develop out a complete Work Breakdown Structure (WBS) to line out how the project will be managed. The WBS has to identify the work packages with the individual tasks and the appropriate persons responsible for identified tasks.

3 PROPOSAL PREPARATION AND SUBMISSION GUIDELINES

3.1 Endorsements and Certifications

A proper certification of the availability of funds is requested.

3.2 Quantity

For the NOI only the original has to be submitted. The full proposals shall be provided in 5 copies including the original signed proposal on or before the proposal deadline.

An electronic version is accepted on or before deadline under the assumption that the signed original will be shipped in parallel.

3.3 Submittal Address

NOI and full proposals shall be delivered to the following address:

EADS Astrium GmbH
Earth Observation, Navigation & Science
attn. Mr. E. Settelmeyer
D 88039 Friedrichshafen, Germany

The electronic version has to be send to the following E-mail address

Eckard.Settelmeyer@astrium.eads.net

3.4 Submittal Deadline and Notification of Receipt

The NOI is due November 13, 2004 and the full proposal February 28, 2005 respectively.

Astrium will notify the proposers in writing that their NOI and full proposals have been received. Proposers not receiving this confirmation within one week after submittal of their proposal should contact Astrium at the address given in Section 3.1.4.

4 ANNEX: TanDEM-X Spacecraft Overview

4.1 TanDEM-X Mission and Orbit

The launch of the TanDEM-X satellite is planned in 2005 using a Russian Dnepr-1 launch vehicle.

The spacecraft will be launched into a sun-synchronous dusk-dawn orbit with the characteristics as summarised in the table below:

Parameter	Mission Orbit
Orbit Type	Sun-synchronous repeat orbit
Repeat Period	11 days
Orbits per day	15 2/11 167 orbits in the repeat
Equatorial Crossing time	18.00hrs +/- 0.25 h ascending pass
Eccentricity	0.0011° – 0.0012°
Inclination	97.443823
Argument of Perigee	90º
Altitude at Equator	514.8 km
Altitude variation	505 - 533 km

Table 4-1: TanDEM-X Mission Orbit

The TanDEM-X satellite is designed such that an in-orbit lifetime of 5 years after the end of 5 months Commissioning Phase will be achieved. Satellite consumables will last for a lifetime of 6,5 years after the Commissioning Phase. The operational performance of TanDEM-X based on the proposed orbit and assumptions on the Ground Segment is analysed in [EL 07]. In addition, [EL 07] shows the key image performance as well as a breakdown of system performance parameters (e.g. pixel localisation accuracy, product location accuracy).

4.2 TanDEM-X Satellite

The TanDEM-X satellite is based on a mission-tailored AstroBus service module and a radar instrument developed according to the AstroSAR concept.

The outer shape of the spacecraft, presented in the figure below, is mainly driven by the accommodation of the X-Band Radar Instrument, the body mounted solar array and the geometrical limitations given by the Dnepr-1 launcher fairing. A standard S-Band TT&C System with full spherical coverage in uplink and downlink is used for satellite command reception and telemetry transmission. The attitude control system is based on reaction

wheels for fine-pointing with magnet torquers for wheel de-saturation. A mono-propellant propulsion system is implemented to allow for orbit maintenance and rapid rate damping during initial acquisition. Attitude and orbit measurement is performed with a GPS/Star Tracker system during nominal operation and a Coarse Earth and Sun Sensor in safe mode situations and during the initial acquisition. A combination of laser gyro and magnetometer allows for rate measurements in all mission phases.

The figures hereafter show the satellite basic configuration. The table which is following summarises the main performance characteristics of the Launcher and the TanDEM-X spacecraft Service Module.

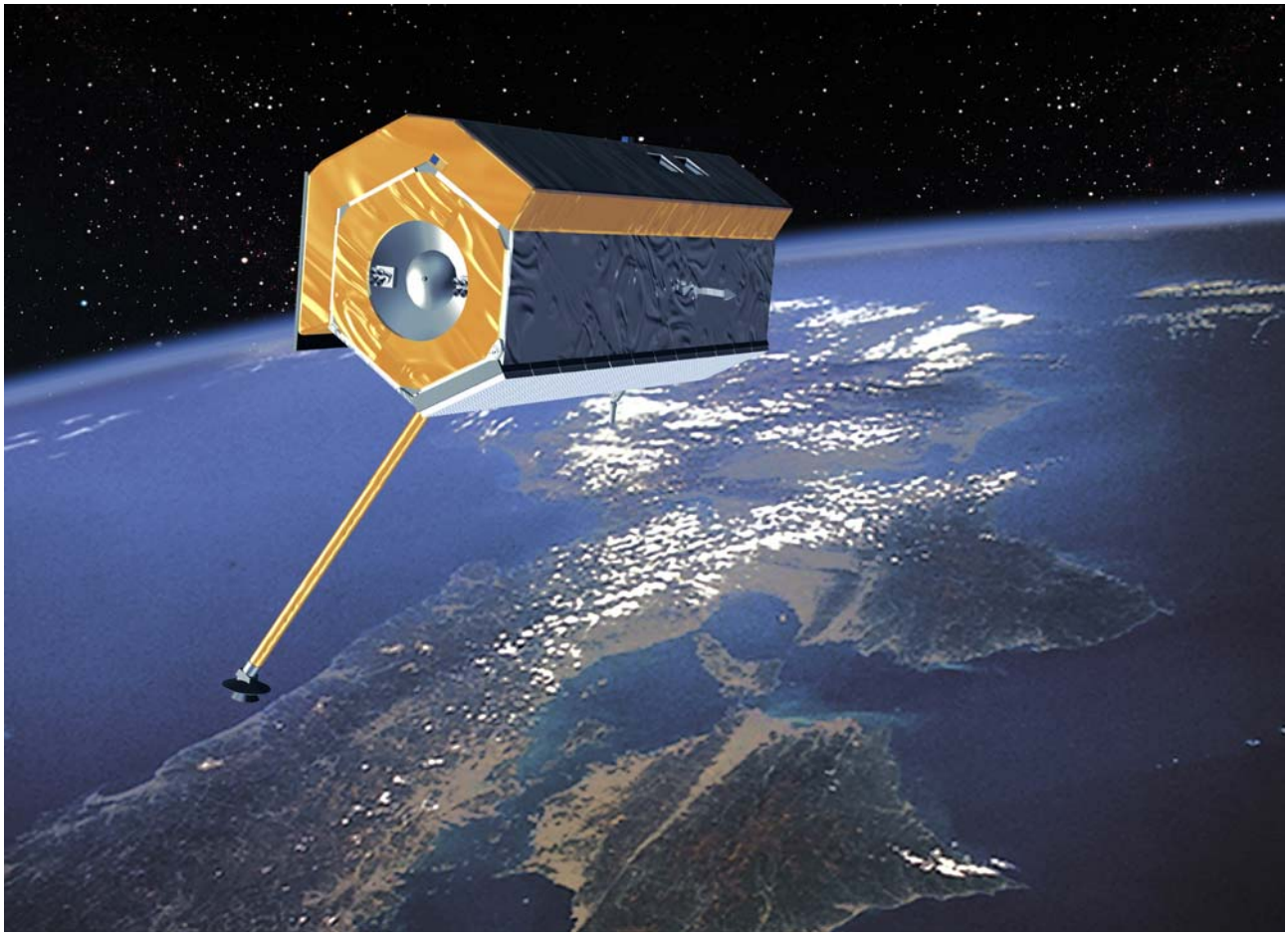

Figure 4-1: TanDEM-X Spacecraft Configuration

LAUNCHER CHARACTERISTICS		
• Type:	Dnepr	
• Launch capability (514 km, SS)	1350	kg
SATELLITE PHYSICAL CHARACTERISTICS		
• Mass:		
- SAR Instrument	506	kg
- TOR Instrument	8	kg
- LCT Instrument	34	kg
- Bus	582	kg
- Propellant	79	kg
- Total Wet	1209	kg
- Mass Margin	11,7	%
• Height	5000	mm
• Diameter	2400	mm
ELECTRICAL POWER		
• Average Power Demand, worst case	736	W
• Power Generation		
- Body Fixed Solar Array		
- Cell Type:	Triple Junction GaInP/GaAs/Ge	
- Cell efficiency @ BOL, AMO, 28°	26,8	%
- Average Power Generation, worst case	856	W
- Margin:	>16,3	%
• Energy Storage		
- Battery Modules	3	
- No. Of Strings / Module	24	
- No. of Cells/String	12	
- Total Capacity	108	Ah
• Power Distribution		
- Unregulated 38 V – 51 V Bus		
- Converter to 28 V ± 5%		

THERMAL CONTROL	
• Individually thermistor controlled heater circuits	
• Temperature Sensors for Housekeeping	
ATTITUDE & ORBIT CONTROL	
• Coarse Earth & Sun Sensors for Acquisition / Safe Mode	
• Star Sensors, GPS for Nominal Mode	
• Reaction Wheels for Attitude Control	
• Hydrazine Thrusters for Attitude and Orbit Control	
• Magneto Torquers for Wheel Unloading	
• Magnetometer and Laser Gyro for Rate Measurement	
ON-BOARD AUTONOMY	
• Autonomy limited to	
- Initial Acquisition	
- Nominal Mode	
- Safe Mode entering after serious failures	
DATA HANDLING	
• Central Processing	
- Processor Type:	ERC 32
• Data Storage	
- RAM / ROM	1024 / 256 kByte
- HK Dedicated Memory	2 Gbit
RF COMMUNICATION	
• Up-Link (S-Band)	
- Carrier Frequency	2025-2110 MHz
- Data Rate	4 kBit/s
- Modulation Principle:	BPSK
• Down-Link (S-Band)	
- Carrier Frequency	2200-2290 MHz
- RF Output Power	0.5 or 1.0 W
- Data Rate	32 kBit/s or 1 Mbps
- Modulation Principle	BPSK

Table 4-2: TanDEM-X Spacecraft Performance Summary

4.3 SAR Instrument

The SAR instrument is an active phased array X-Band system with 384 TR-Modules and is capable of operation in two polarisations, H and V. Beam steering is possible in azimuth (± 0,75°) and elevation (± 20°). Generated SAR data are stored in a Mass Memory Unit of 256 Gbit EOL capacity before they are downlinked via a 300 Mbit/s X-Band System. The SAR antenna is body fixed and its approximate dimensions are 4800 mm in length, 800 mm in width and 150 mm in depth. The table below summarises the main parameters and performance characteristics of the TanDEM-X SAR Instrument.

Instrument Spotlight Mode Performance:		
Product coverage hi-res	5 x 10	km
Product coverage spotlight	10 x 10	km
Slant Range Resolution, 1pol	< 1,2	m
Slant Range Resolution, 2pol	< 2,4	m
Geometric Resolution along, 1 pol, hi-res	< 1,0	m
Geometric Resolution along, 2 pol, hi-res	< 2,0	m
Geometric Resolution along, 1 pol, spot	< 2,0	m
Geometric Resolution along, 2 pol, spot	< 4,0	m
Noise equivalent σ_0 @45°	< -19	dB
Ambiguity Ratio	< -17	dB
Instrument Stripmap Mode Performance:		
Product coverage along	< 1500	km
Product coverage across (1 pol)	30	km
Product coverage across (2 pol)	15	km
Geometric Resolution across, 1 pol	< 3	m
Geometric Resolution across, 2 pol	< 6	m
Geometric Resolution along, 1 pol	< 3	m
Geometric Resolution along, 2 pol	< 6	m
Abs. Radiometric Accuracy, 1 pol	< 1	dB
Noise equivalent σ_0 @45°	< -19	dB
Ambiguity Ratio, 1 pol	< -17	dB
Instrument ScanSAR Mode Performance:		
Product coverage along	< 1500	km
Product coverage across	100	km
Geometric Resolution across	16m / 4 looks	
Geometric Resolution along	16m / 1 look	
Noise equivalent σ_0 @45°	< -19	dB
Ambiguity Ratio	< -17	dB

Instrument Key Parameters:		
Centre Frequency:	9650	GHz
Chirp Bandwidth (adaptable chirp):	150(300[1)])	MHz
Radiated RF Power	ca. 2	kW
System Noise figure	5	dB
Nominal Radar duty cycle:	13-18	%
Maximum Radar duty cycle:	20	%
Quantisation of signal:	8 bit I / 8 bit Q	
SAR data compression:	online BAQ	
Pulse Repetition Frequency Range:	2,2 – 6	kHz
Polarisation: HH / VV / HV / VH (single or dual)		
Antenna Aperture	0.7 x 4.8	m^2
Internal Peak Data Rate	2.64 (5,28[1)])	Gbit/s
Typical Data Rate (SpotLight)	360	Mbit/s
Typical Data Rate (StripMap)	580	Mbit/s
Data Storage & Downlink:		
Mass Memory Capacity (EOL)	256	Gbit
X-Band gross Down-Link Data Rate	300	Mbit/s
Instrument Internal Power Distribution:		
Converter to 115 V 30 kHz AC for Instrument Front End		

[1)] 300 MHz Experimental Mode

Table 4-3: Instrument Key Parameters and Performance