QUASAT

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ABSTRACT: QUASAT was proposed to ESA as a joint ESA-NASA medium scale mission for space VLBI in December 1982. At the time of writing, four and a half years later, QUASAT has passed through an Assessment Study in ESA, a pre-Phase A study in NASA and has just entered an ESA Phase A study in European industry, supported by JPL and Australian and Canadian space interests. If QUASAT is selected to fly at the end of the Phase A study, it will be launched in 1995-1996. The scientific goals, mission concept and current status are reviewed this paper.

1. INTRODUCTION

The quest for higher angular resolution has taken radio astronomy a long way since the first two element interferometric observations were made in 1946 with baselines of a few hundred meters. Current VLBI networks and the planned VLBA in the USA utilize the whole Earth as a radio telescope to achieve not only sub-milli-arcsecond angular resolution, but also good quality images. The next obvious step for the interferometry technique is to go beyond the confines of the Earth and position an element or elements in Earth orbit.

Apart from the considerable technical challenge of going into space, there are sound scientific reasons for doing so. Foremost amongst these is high quality imaging at even greater angular resolution than on the Earth to investigate those sources and source components still unresolved on Earth baselines. In addition, prospects for imaging in the equatorial region of the sky, and in the southern hemisphere, are significantly enhanced by the presence of a space element to provide adequate U-V coverage for the first time. "Rapid" imaging on timescales of a few hours for variable galactic sources is also made possible, again because of enhanced U-V coverage compared to ground based arrays.

QUASAT was proposed to ESA as a joint ESA-NASA space VLBI mission in November 1982 by an international group of astronomers. An ESA Assessment Study was carried out from October 1983 to June 1985 in

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parallel with a pre-Phase A study in NASA. QUASAT was approved for Phase A in Europe in February 1986.

The aftermath of the Challenger crash in January 1986 forced NASA to delay consideration of new projects in the Explorer program, including QUASAT, and caused ESA to re-evaluate the cooperative framework under which QUASAT had been studied up to that time. This re-evaluation resulted in a mission concept with ESA as the leading agency but with substantial support from JPL, and Australian and Canadian space interests (ESA SCI(86)8). This new concept was approved for an ESA Phase A in February 1987.

In the meantime in 1986, a succesful demonstration of space VLBI was made at the first attempt using the NASA TDRSS satellite (Linfield et al., these Proceedings). This result emphasised that space VLBI is a viable, and potentially very valuable, space astronomy discipline.

2. SCIENTIFIC GOALS

With QUASAT we expect to obtain high quality images at resolutions of ~60 micro arcsec at 22 GHz in the "final" orbit and lower quality images at angular resolutions of 40 micro arcsec in the "initial" orbit (see discussion on orbits in the next section). The primary goal will be to probe the nuclei of radio galaxies and quasars more deeply and in greater detail than is possible with ground-based networks alone (see Table 1). The scope of applications of VLBI demonstrated by the contributions at this Symposium is evidence that the scientific goals of QUASAT will be wide-ranging. One other area is worth mentioning as potentially very important. This is the use of astrometric techniques on H_2O masers in nearby galaxies to directly measure distances to those galaxies (Reid et al, these Proceedings).

The main scientific goals are listed in Table 2 and described in detail in the Assessment Study Report ESA SCI(85)5 and in the QUASAT Workshop Proceedings ESA SP-213.

Table 1: Spatial resolution at 1.35 cm wavelength. (H_o=100 km^{-1} Mpc^{-1}, q_o=0.5)

Object	Distance	Linear size for 60 micro-arcsec beam	
Galactic Center	7.1 kpc	6.7×10^{12} cm	0.4 A.U.
Centaurus A	5 Mpc	4.6×10^{15}	1.8 light days
NGC 1275 (3C84)	53 Mpc	4.6×10^{16}	0.6 light months
3C273 (z=0.158)	491 Mpc	3.4×10^{17}	4 light months
3C345 (z=0.595)	1992 Mpc	7.4×10^{17}	0.8 light year

Table 2: QUASAT Scientific Goals

Measurement of high brightness temperature phenomena in:

- **Active Galactic Nuclei**
  Quasars, Radio Galaxies, BLLacs/Blazars, Seyfert I+II, Liners
  Images on scales of accretion disk, broad line region, narrow line region
- **Newly-formed stars**
  masers, flow patterns, magnetic fields, densities
- **Evolved stars**
  masers, mass-loss rates, densities
- **Binary flare stars**
  images of giant flares, energy generation
- **X-ray binary stars**
  images of mini-jets, collimated flow

Extragalactic masers
properties of neutral gas in active nuclei

Scattering properties of the interstellar medium

Distances within our galaxy

Distances to nearby galaxies - Hubble Constant

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3. MISSION CONCEPT

3.1. General

QUASAT is a free-flying satellite carrying a 15 m class radio telescope in elliptical orbit around the Earth. The radio telescope will be deployed in space, and used to make interferometric observations of radio sources in conjunction with the major ground-based VLBI arrays in Europe, USA, Australia and the USSR. The mission design lifetime is 2 years, but an operational lifetime of 5 years is expected.

The space-borne antenna will be capable of observing in both hands of circular polarization simultaneously at any two of the frequency complement of 22, 5, 1.6 and 0.3 GHz, and will relay the received signals via a digital or analogue link directly to telemetry stations (NASA DSN and/or ESA) on the ground (see Figure 1). The bandwidth of the dual polarization link will be at least 32 MHz in each hand of polarization. A phase/frequency reference for the antenna in space, stable to about 1×10^{-14}, will be based on hydrogen maser oscillators on the ground and relayed directly to the satellite via a two-way link from the telemetry stations in turn. All communication with the space element will be through one or more telemetry stations in the network.

processing facility of the European or US VLBI array for correlation with similar tapes from the ground VLBI arrays. After correlation and calibration the data will be sent to the principal investigators for further analysis.

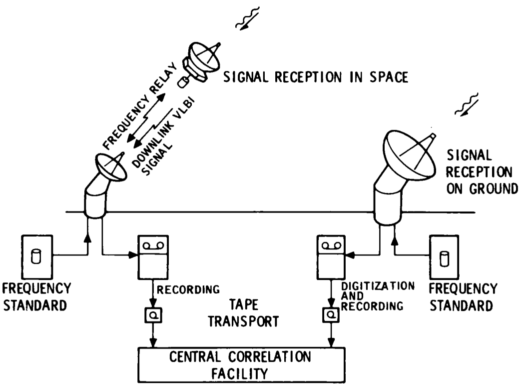

Figure 1. Schematic diagram of a space/ground VLBI system.

3.2. Orbits

Two orbital situations have been considered:

1) an "imaging" orbit, optimized for very high quality imaging with the European and US ground arrays. The perigee altitude is 5700 km, the apogee altitude 12500 km, and the inclination 63°. This orbit would require a dedicated launch since no passengers to this orbit have been identified. Reduced levels of funding projected for the next medium scale mission in ESA, make the cost of getting to this orbit unattractive.
2) a "two-tier" orbit to provide high angular resolution with lower quality imaging, the "initial" orbit, before bringing the satellite down to lower altitudes for higher quality imaging at somewhat lower angular resolution, the "final" orbit, after perhaps 1 or 2 years. The initial orbit has perigee and apogee altitudes of 5000 and 36000 km respectively, an inclination of 30° and a period of $12^{h}.2$. The final orbit has its apogee altitude reduced to 22000 km and the period to $7^{h}.75$. The advantage of this concept is that QUASAT would share a launch to geostationary transfer orbit, and thus share the costs. Figure 2 depicts the two-tier orbit.

Computer simulations of the imaging potential of QUASAT in the "imaging" orbit have demonstrated that superb results are obtained (ESA SCI(85)5). Simulation of the imaging potential of the "initial" and "final" orbits is in progress at Jodrell Bank as part of the Phase A study. Table 3 lists the angular resolution and sensitivity expected for QUASAT in the "final" orbit at its observing wavelengths of 1.35, 6, 18 and at 92 cm.

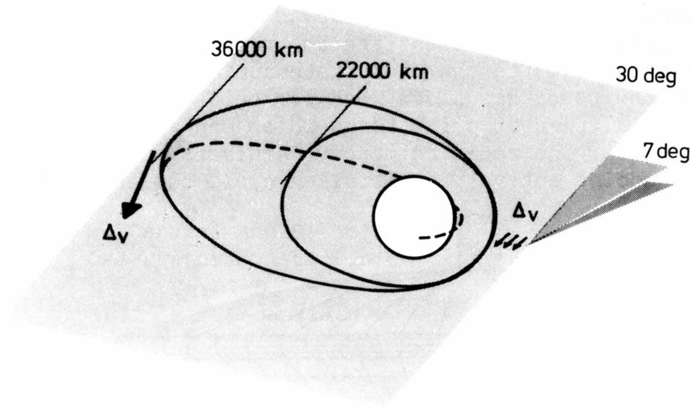

Figure 2. The orbit injection sequence, and two-tier orbit.

Table 3: Angular resolution and sensitivity of QUASAT

λ (cm)	Angular resolution* (micro-arcsec)	RMS noise per resolution element (continuum)**	RMS noise per spectral channel+	Frequency (GHz)
1.35	60	1 mJy	35 mJy	22.0-22.50
6	270	0.5	-	4.72-5.02
18	800	0.3	20	1.60-1.72
92	4000	3	-	0.324-0.327

* this is the dimension of the synthesized beam. Information on size and position angle is in fact available on scales 2 to 3 times smaller than this.

** for a 48 hour observation assuming there is a sufficiently strong feature (~150 mJy at 1.35 cm, ~50 mJy at 6 and 18 cm and 300 mJy at 92 cm) present in the map to allow self-calibration.

\+ for a 48 hour observation assuming there is a spectral feature present of sufficient strength (~20 Jy at 1.35 cm and ~5 Jy at 18 cm) to allow self-calibration.

3.3. Science Payload

The Assessment Studies have shown that the overall mission, which is based on current VLBI and spacecraft engineering practice, is technically feasible. As far as the spacecraft is concerned the major new aspect is the deployable antenna. Two antenna configurations have been studied; in ESA a 15 meter diameter inflatable space rigidized structure developed by Contraves, Switzerland (see Figure 3), and in

NASA a 15 meter wrap-rib deployable mesh structure developed by the Lockheed Corporation, California. Both appear to be satisfactory for the mission. Other areas of development are the radio astronomy feeds and an active cooling system for the radio astronomy receivers. An industrial study of the feeds has shown good performance for a compact three frequency co-axial feed at prime focus which can also accommodate a dipole array for 92 cm. The radio astronomy receivers will be based on HEMT amplifiers, cooled actively by Stirling cycle coolers.

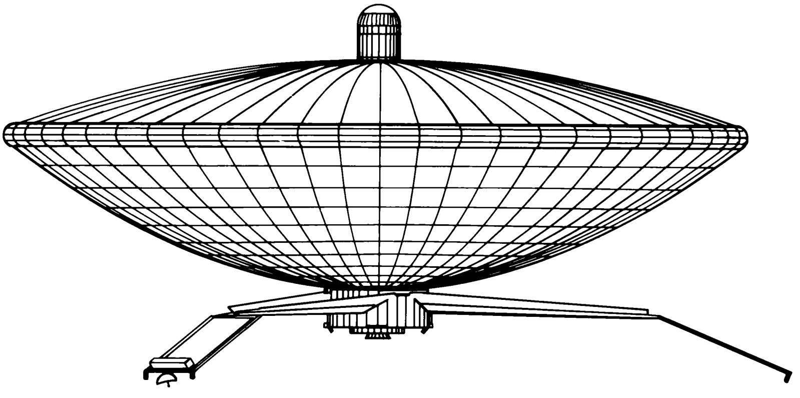

Figure 3. ESA concept for the orbiting antenna.

4. CURRENT STATUS AND FUTURE DEVELOPMENT

The industrial Phase A study finally began on 12 May 1987 and is being conducted by a European consortium led by Aeritalia in Turin, Italy. NASA has at the same time allocated funds to JPL for support of the ESA Phase A, particularly in the area of antenna technology, links, tracking, and operation. Details of the Australian and Canadian participation are currently under discussion.

The "science payload" - feeds, receivers, coolers, synthesizers, etc, but excluding the antenna - is to be studied by the radio astronomy community in parallel with the Phase A, with the aim of establishing the costs and effort required in constructing space qualified payload elements. Institutes in Europe, USA, Australia and Canada have been identified for the various elements.

QUASAT will enter a competitive selection round in ESA at the end of 1988. Assuming it is selected, the project will then move into a detailed design phase in 1989-90, followed by the construction and testing phase from 1990-1994. Final integration of the spacecraft will occur in 1995 with launch in that same year or in 1996.