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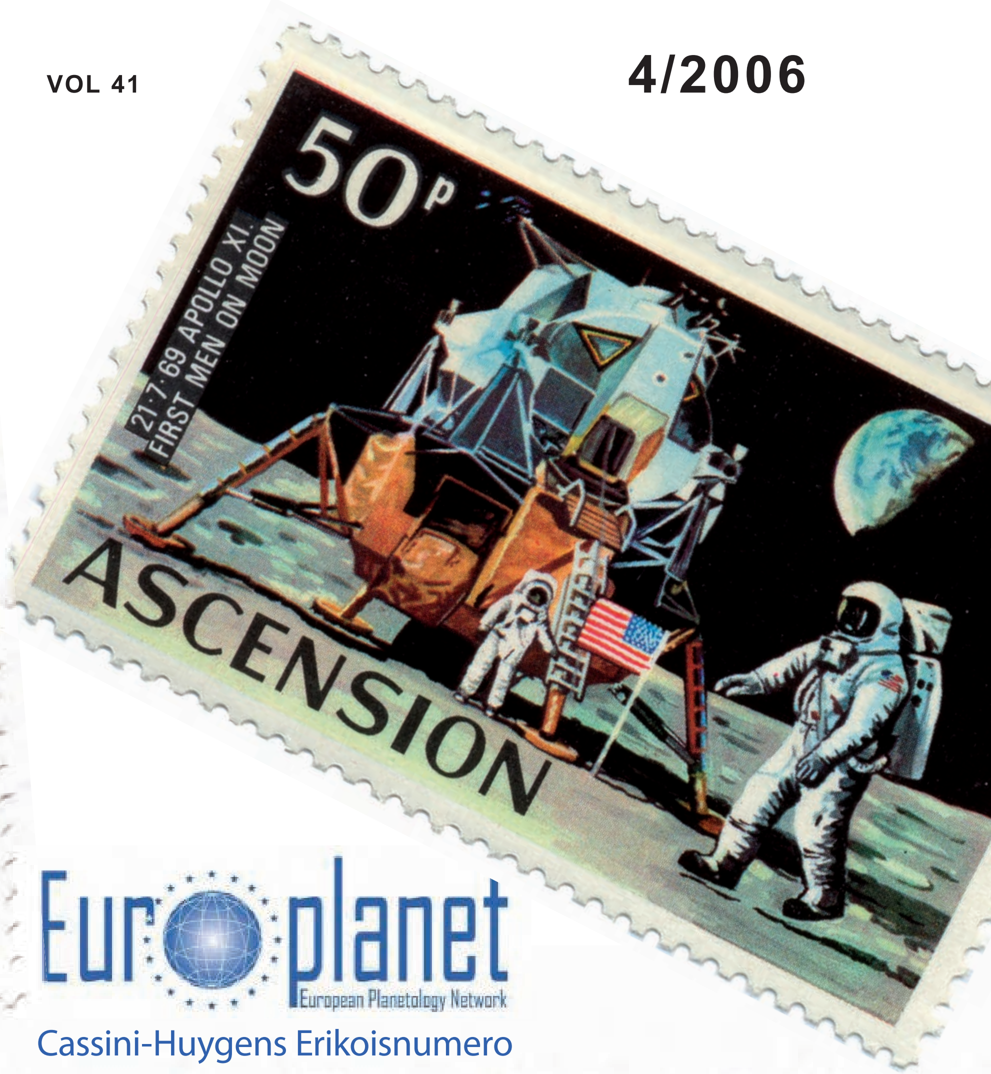

Europlanet
European Planetology Network

Cassini-Huygens Erikoisnumero

Pääkirjoitus

Tervetuloa uudistuneen Avaruusluotaimen muhkean Europlanet (europlanet.cesr.fr) joulunumeron ääreen! Ensimmäistä kertaa mukana tulee myös CD -rom levy täynnä avaruusasiaa ja lehden juttuja tukevaa materiaalia!

Vuoden alussa tutkaillaan historian avaruuspostimerkkejä (s. 4). Olin sattumoisin juuri viime kesänä Ateenassa sikäläisen vastaavan näyttelyn avajaisissa ja silmiin pisti että maittain jaetussa näyttelyssä Suomi oli edustettuna ainoastaan yhdellä merkillä isäntämaa Kreikan tavoin. Ehkäpä piakkoin saamme vaikkapa Aurinkotuulipurjetta (s. 5) kuvaavan postimerkin uuden Suomalaisen innovaation kunniaksi!

Uusia vakiopalstan pitäjiäkin on haalittu Avaruusluotaimen riveihin (s. 8). Ilmatieteen laitoksen tutkija Tiera Laitinen tulee jatkossakin arvostelemaan alan uutuuskirjoja. Kiitos kaikille juttuja ja lukijakirjeitä lähettäneille, lehti on paksumpi ja entistä komeampi teidän aktiivisuutenne ansiosta! Jatketaan samaan malliin!

Sini Merikallio ja Maan pinnalla taivaltava Feromoni Kuu

Sisältö

Kannen kuvassa Postimuseon näyttelyn satoa ja Castorin Supikoira tiimi (© Eero Alkkiomäki). Katso Supijuttu sivulta 22 ja videot liiterompulta!

Takakannessa taiteilijan näkemys Huygens laskeutumisesta Titanin pinnalle, myös tästä hieno video liiterompulla ja kaksi isoa juttua tässä lehdessä (s. 10 - 18).

Suomen avaruustutkimusseura ry – Sällskapet för astronautisk forskning i Finland rf on 1959 perustettu yhdistys, jonka tarkoituksena on harjoittaa avaruusalan kokeilu-, harrastus-, tutkimus- ja tiedotustoimintaa sekä toimia avaruustutkimuksesta kiinnostuneiden henkilöiden yhdyssiteenä. Seura on Suomen äänivaltainen edustaja Kansainvälisessä astronautiikkaliitossa (IAF; International Astronautical Federation). Suomen avaruustutkimusseura julkaisee Avaruusluotain-lehteä ja ylläpitää kirjastoa, josta voi lainata alan kirjallisuutta, kuva- ja videomateriaalia. Seura järjestää avaruusaiheisia näyttelyitä ja tapahtumia sekä ylläpitää aihepiiriin liittyvää harrastustoimintaa.
Työ- ja kerhotila on osoitteessa Kauppalantie 6-8, 00320 HELSINKI (puh/vastaaja 09-5874433).
Vuoden 2007 jäsenmaksut (sisältää Avaruusluotain- lehden) ovat:
Varsinaiset jäsenet 17 EUR, Juniorijäsenet (alle 15 v.) 6 EUR, Nuoriso-/ opiskelijajäsenet 8 EUR, Järjestö-/Yritysjäsenet 170 EUR

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Story of Huygens Radar Altimeter

In 1984 ESA/NASA started a joint assessment study of the Cassini mission to Saturn. The project was selected by ESA in 1988 and their part would be a dedicated probe to land on Titan (one of Saturns moons). Mr. Huber (then Head of Space Science Dept. stated in his introduction address to the Titan Symposium, in 1991 "one of the delegations (I believe it was the Swiss) suggested that the Titan probe be given a name of it's own. Within hours the executive came up with the name "HUYGENS", which very much pleased the Dutch delegation".

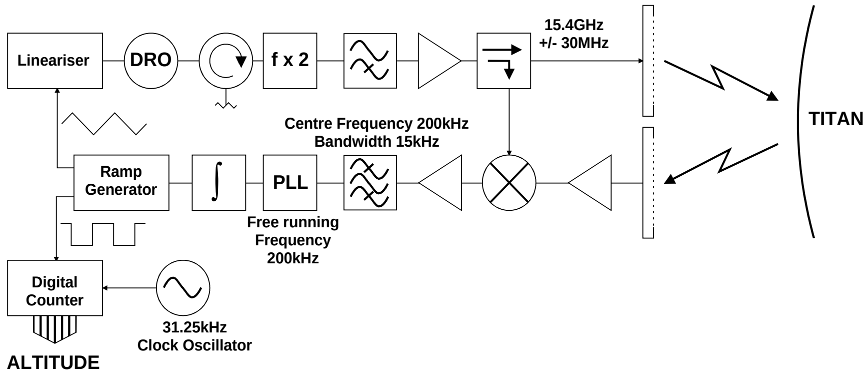

Fig.2. The Radar block diagram

WHY GO TO TITAN?

Voyager 1, in 1980 passed close enough to photograph Titan, which is just larger then Mercury or our Moon, but this showed little detail, the surface being covered in cloud.

Fig 1. Titan (JPL/NASA)

In those days it was known that its atmosphere had a high Methane content and this could be converted into heavier hydrocarbons (ethane, benzene..) by ultraviolet radiation. The addition of carbon from cometary encounters led to the possibility of cyanide, simple nitriles, adenine, etc.. These in turn could lead to nucleic acids, more complex organic molecules and potentially a similar situation as early Earth, for the creation of life and obviously worth looking into.

HOW TO GET THERE?

This would be the deepest space mission for ESA (by a long way) and the furthest planetary landing ever (9.5 times the Earth-Sun distance away). After launch the eventual journey would take many gravity assisted planetary "fly-by's"; first Venus, then after a swing outside the Earth's orbit, back to pass Venus again and then quickly past the Earth and then a final fly-by Jupiter before targeting Saturn. All in all just less than 7 years. In those days this was difficult to believe possible.

Once at Saturn, the plan was to orbit twice and then release HUYGENS for a one month "cruise" phase, completely switched off. A triple redundant CMOS timer would then "wake" the craft a few hours before it hit the atmosphere – indeed a responsible subsystem! Then an accelerometer would detect the 0.7g point after the 20g atmospheric entry shock and start the timing. The first of a series of parachutes would be deployed to slow the descent to a speed where useful measurements could be made. The timing would then be updated by the radar once "lock" to the radar return signal had been established.

YLINEN ELECTRONICS RADAR ALTIMETER

In the early 1990's YLINEN Electronics indicated their willingness to play part in this adventure and it was proposed that they should contribute the Radar Altimeter. Even with the gravity assists, getting to Titan would take a lot of energy, thus mass, accommodation and electrical power were all at a premium. This made the choice of measurement instruments critical and they should be balanced to get the maximum data return.

For HUYGENS, radar had been rejected as a sensor (in preference to cameras and other instruments) however, descent experiment timing could not rely on the autonomous computer system, to be programmed with the then limited data obtainable from Earth measurements. Thus a radar Altimeter was specified.

The initial requirements were for a cheap off-the-shelf solution, capable of measuring altitude from 10km down (the area of most interest and most timing uncertainty). The fact that the surface reflectivity, surface model and atmospheric attenuation were unknown was just a detail.

During initial design other requirements emerged. The radar should of course be of minimal mass (<1.8kg), use minimum power (<5 watts) and values chosen for reflectivity and atmospheric loss were very much worst case (-20dB & –2dB).

To demonstrate early confidence YLINEN made a (company funded) prototype and flew this on a light aeroplane up to 3km. It was interesting to be at a late Phase A meeting with ESA, when they asked "how can we be assured that the design you propose will work". Mr. Ylinen reached in his bag and put the prototype on the table, saying "Well, we have built one and flown it – and it works!". ESA was not used to such obvious capability and this did ease progress towards the real system.

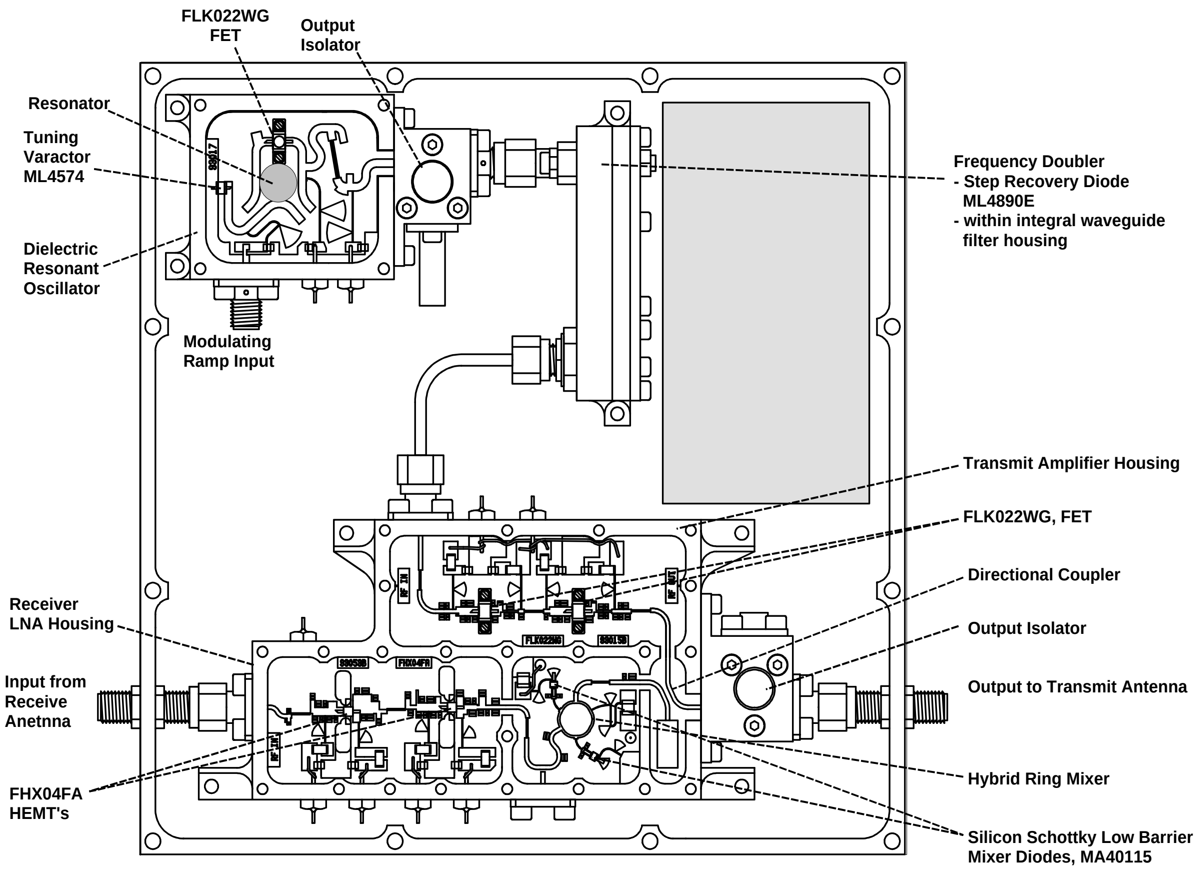

Fig.3: the Radar Microwave configuration

THE DESIGN

YLINEN proposed an existing design based on the FMCW (Frequency Modulated Continuous Wave) technique. A continuous signal is transmitted (~15GHz), which is swept up and down in frequency by 30MHz. Because of the propagation time, the reflected return signal will be at a different frequency, from that being transmitted. By mixing the transmitted signal with the return signal, this frequency difference can be found and will be proportional to the delay time and thus altitude.

In reality the radar sweep rate was adjusted by a servo system to give a constant difference frequency and thus the sweep period would be proportional to the altitude.

A dielectric resonance oscillator (~7.5GHz) was used as the signal source. This was voltage tuned over the required sweep range. The output was doubled in frequency and applied to the transmit amplifier (2 stage FET +23dBm) and then radiated by a dedicated transmit antenna. The return signal, received by the receive antenna, was amplifier by a low noise amplifier (2 stage HEMT, 30dB gain, 2.3dB NF) and mixed with a low level transit signal, coupled from the transmit amplifier output.

All this was housed in a single aluminium box, machined from solid to meet the mass requirement, a wall thickness of 0.7mm was used with integral strengthening ribs. This alone took several manufacturing attempts and development of stress treatment, before a “square” housing could be relied on.

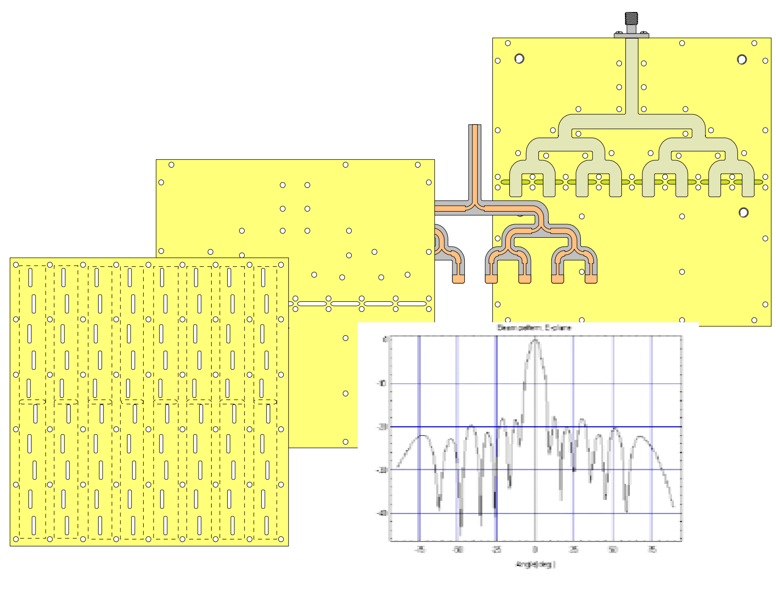

Fig.4 The transmit (or receive) antenna test and validation

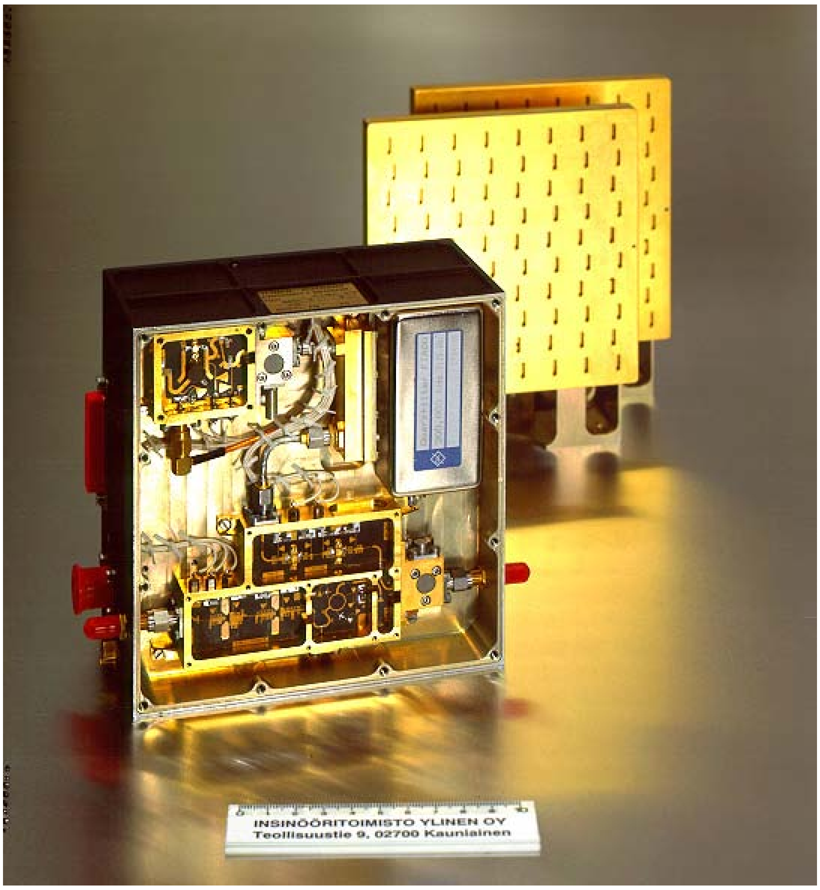

Fig.5. The Radar Electronics and (behind) the Antenna.

ANTENNA TESTING

In the antenna, the radar transmit signal was applied to a suspended microstrip substrate 1:8 divider. The divided signals were then radiated into waveguide cavities, with 10 radiating slots on the opposite side, effectively a fixed phased array. The antenna had to be outside the probe and thus of rugged design. A three plate, aluminium construction was chosen. This provided a beamwidth of ~8 to 9 degs.

It is very well to build a radar (and even fly the prototype) but it must be tested thoroughly, not only for delivery, but during all subsequent stages of spacecraft integration. Thus an on-ground test system was also developed. The main problem was to accurately delay the transmitted signal without destroying its' properties.

Surface acoustic delay (SAW) lines were selected as providing the best option. The transmitted signal was frequency converted to a lower range and applied to the SAW delay devices. The delayed signals were then upconverted to the operating frequency and returned to the radar receiver. Test coupling points were not allowed and thus "antenna caps" (identical antenna mounted in absorbing structures) were mounted directly over the radar antenna.

This "turn-around converter" system provided five switchable delays; 150m, 1km, 3km, 3km and 3km, which enabled the radar to be validated at 8 specific altitudes (functional validation). Calibrated attenuators also enabled the receiver signal to be reduced and to establish the point where the servo could no longer track the signal and the system would loose (or gain) "lock". This was the maximum altitude point (by amplitude) and was used to evaluate the point during the descent where the radar should acquire first "lock".

MODEL PHILOSOPHY

An ENGINEERING MODEL (EM) was first built (after the prototype) to demonstrate the final design. The QUALIFICATION MODEL (QM) was then built and was tested over 10% in excess of the operational temperature range, in vacuum. It was also vibrated to acceleration values 10% greater than those expected, including 20g shocks to simulate the HUYGENS atmospheric entry. This model was also subjected to rigorous EMC/ESD testing to ensure electrical and magnetic compatibility with the rest of the spacecraft.

During this phase it was realised that the antenna outside the heated probe would experience down to –200C°. Thus they were measured, at –200C°, in an YLINEN cryogenic chamber and it was found that their bandwidth centre frequency changed by ~70MHz. This was not critical (in 400MHz) but caused the re-design of the antenna, by scaling all microwave dimensions such that they worked with the correct centre frequency at this temperature.

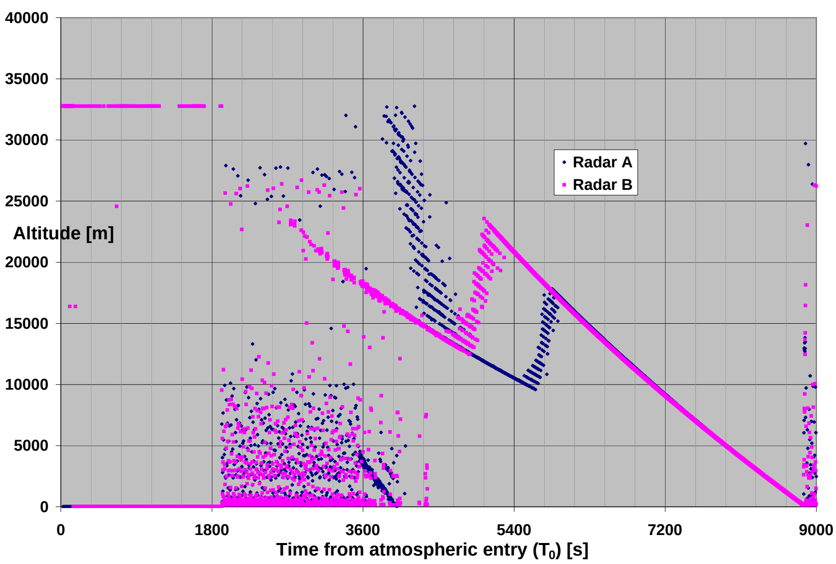

Fig.6. The measured altitude during descent

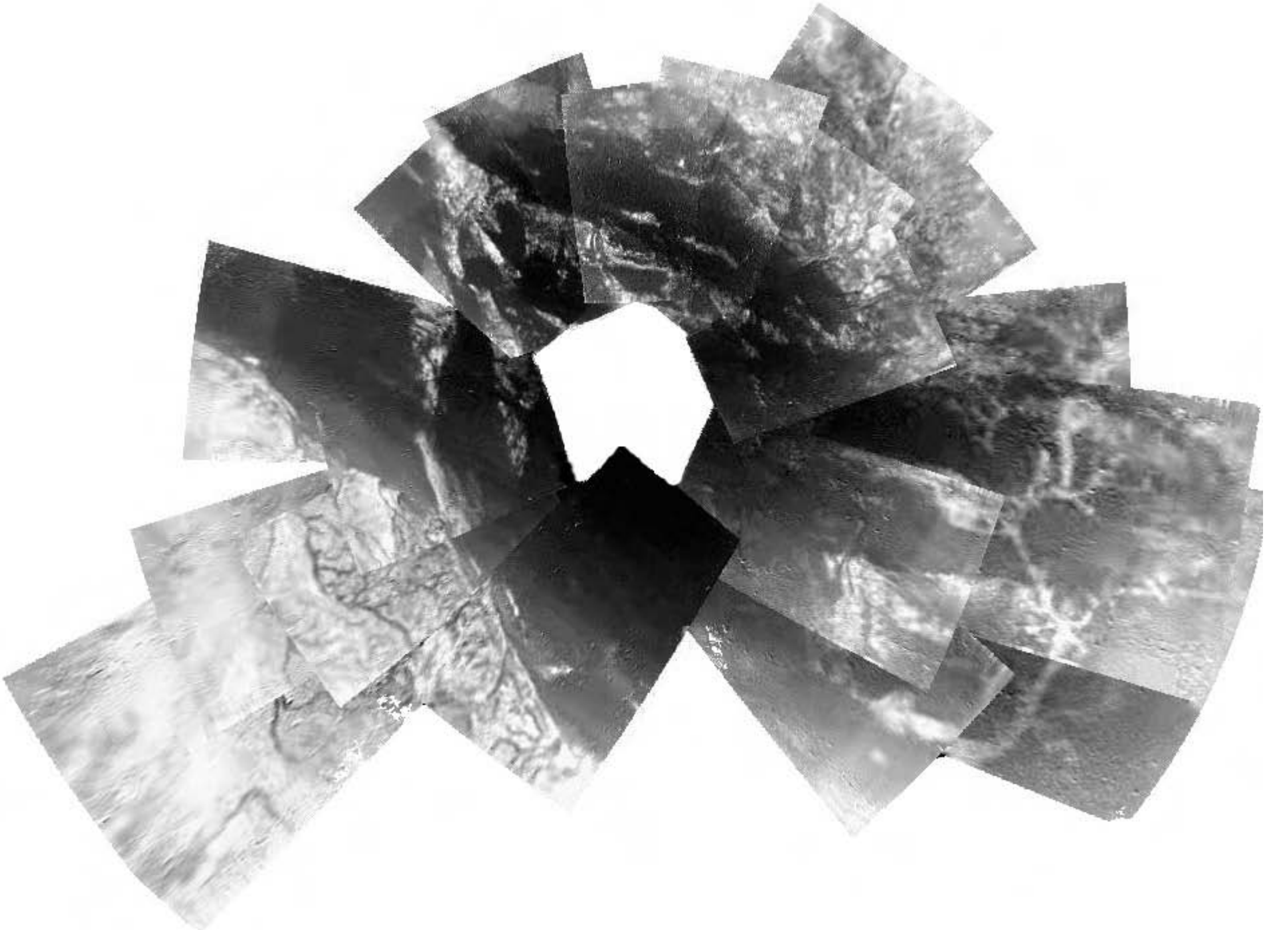

Fig.7. The surface mosaic from 10km (© ESA)

In order to correctly validate the QM, it must use Space Quality components. This presented a few difficulties when finding equivalents and although the design was not compromised the previous ample range (amplitude) margin was reduced such that under certain QM tests it was marginal.

This was not acceptable to the project, until it was pointed out that most recent measurements of the Titan reflectivity showed not –20dB but between –3 and -6dB. It was also pointed out that surface model had not been specified and if YLINEN selected a more favourable model all requirements could be easily met. It showed the cooperative nature of the project, that ESA then agreed to impose the worst case surface model but relax the normal reflectivity from –20dB to –10dB.

It should be noted that two complete "hot" redundant systems were used at 15.4GHz and 15.8GHz, to ensure reliability of the system. After the QM the Flight Models (FM) were built. An additional Flight Spare was also built and the QM was re-furbished to provide two complete Flight Spares.

LAST MINUTE CHANGES

During the early part of the QM programme it was realised that the radar produced other valuable data, in addition to the altitude. The radar return signal would provide the first short range measurements of reflectivity and also provide a low resolution assessment of the type of surface structure. Consequently additional outputs were requested; the radar return signal strength and the sweep timing signal. Also it was requested that the radar be switched ON above 40km and all steps taken to provide the best possibility of achieving lock as high as possible and hopefully 40km.

MORE PROBLEMS?

The complete system was delivered in 1996. The launch was successful on 15th October 1997. Then we sat back and waited.

Cassini & HUYGENS came past us again 18th August 1999 and all looked good - until an engineer at the Huygens ground station realised that in simulations the signals transmitted upwards from the probe and through the parachute, would not be relayed by Cassini (back to Earth), because they would be outside the Doppler bandwidth and not compensated for the relative velocity of the two spacecraft.

This episode demonstrates how effectively ESA can react to such an enormous crisis. The orbit parameters were changed to reduce the Doppler shift to within operating limits, requiring three Saturn orbits before release and an orbit correction to Cassini after release of HUYGENS.

WHAT HAPPENED?

On Christmas day 2004, HUYGENS was released form Cassini. It's mission had now fully started. Cassini was the last mission to be allowed to use Radio-isotope Thermal Generators, necessary when over 10

AU from the sun. HUYGENS was now completely shut down except for the mission timer and relying from now on totally on battery power.

The timer worked, the parachutes worked and the radar worked. By the end of 14th January 2005 HUYGENS was on the surface. Figure 6 shows how both radar performed. It should be mentioned that they both have an independant "search" mode. Once switched on, the FMCW modulation period is swept from equivalent Titan surface level to 32km. When the return signal appears through the noise, this is detected and the radar servo "locks".

Radar switch ON can be seen just after 30mins. From then until around 1 hour, random "locks" are seen as the modulation is swept through the altitude search range. Just after the hour radar A starts to spuriously lock and un-lock.

Both radar achieve a false "lock" before the 1hour 20mins point, displaying an altitude of 13km. This is believed due to a double sweep counting effect, an inheritance of the change of maximum range requirements so late in the programme.

As the return signal becomes stronger, Radar B recovers completely, a little after 1hr. 20min giving a steady altitude of 22km. Radar A continues in the double lock state until about 18km when it also recovers. It should be noted that this effect is wholly predictable so that both radar can be said to accurately be measuring from over 23km and the original "design goal" requirement was 20km!

From that point altitude measurements track very much better than the original requirement of 10% (certainly better than 1% at high altitudes) and agree also within a few percent of the post processed pressure derived measurement.

RESULTS

HUYGENS has undoubtedly been a great success. The chemical and physical composition of the atmosphere are now much better known. The probe landed in mud and continued transmitting for much longer than expected. The surface shows similar geological mechanisms to the Earth, with rivers and lakes but based on liquid methane!!

Work continues even now analysing the data to fully profile the atmosphere and surface, potentially for future missions. For much more results you are recommended to review the ESA web site **http://www.esa.int/SPECIALS/Cassini-Huygens**.

Here at Ylinen, of course, we had a party. The radar had been delivered in 1996 and by the 14th January 2004 the team was well dispersed. However, all team members were located and we celebrated, with Champagne, the success of our radar.

ACKNOWLEDMENTS

Spacecraft missions are not made by single persons, companies or (in Europe) countries. I would like to thank all involved for one of the most exciting and stressful five years. In particular ESA and JPL for their excellent management, guidance and help. YLINEN provided the Radar for the Command & Data Management Unit, built by Laben S.p.A (Milan, Italy). In turn the CMDU was provided to Aerospatiale (Cannes, France), who built the probe (both companies now part of Alcatel-Alenia Space). To both these companies we offer our thanks and appreciation of the time spent working together.

Finally I recommend all to go to the ESA web page "Sounds of Titan". On there is an audio file, of the radar sweeping modulation as the probe descend to the surface. As I consider things, this is "our signature tune!". (editors note: See also the attached CD for Huygens descent videos and pictures!)

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Fig.8 the YLINEN in 1996 waiting for the delivery van. In the box is the HUYGENS radar which is now on the surface of Titan.