Australian Space Development Conference 27 July 1998 Rough Notes

27 July 1998 Monday

Talk 1: David Kwon, Asia-Pacific Space Centre

operating seven years so far. Now looking at Christmas Island. keeping low profile. First thought this might be an easy project. But halfway through realised it's really hard both engineering and political. Chicken and egg situation, Russians ask Australian government for support, but Australian government says no support unless real project first. Russian space agency, Starsem. Propose to use Soyuz launch vehicle. Land and financing negotiating, Bankers Trust, to be finalised by the end of this year. Expect full process finalised early next year. Russians would do the launchpad and facilities. Astrotech would do payload processing. Civil and building works will be done by an Australian company, including environmental impact.

3.5 million spent so far. All subject to land transfer and environmental impact. Predict $150 million market in the next 10 years. Existing facilities are not enough. Christmas Island previously mostly phosphate mine, now resort and Casino. Launch site located on the southernmost point. Purely a commercial launch site. Communications, remote sensing, GPS, etc. Requires new airport and new port facilities. 14 MW power generator. existing road to launch site. 200 m above sea level. No cyclones or weather problems. Close to Asia, 350 kilometres from Indonesia, 1.5 hours from Singapore.

Talk 2: Sinclair Knight Merz (Australia), Dr Malcolm Hall, Dan Raymond.

Have done environmental impact assessment of launch facilities in Australia. In the past there was Woomera in the 50s and 60s. Cape York was proposed in the 1970s. In recent times people have considered Gun Point & Melville Island, Darwin and Cape York. Now APSC is looking at Christmas Island. Kistler is looking at Woomera, groundbreaking this week.

Standard series of steps.

- Initial advice statement (InAS), physical scale, list environmental issues, government and public comment.
- Terms of reference for investigation (TOR), issued by government, environment, fuel, transport, industry, social. Includes rehabilitation, decommissioning, security, risks of failure and consequences, launch site, drop zones.
- Environmental impact statement (EIS) public response handled by proponent, or
- Public environmental report (PER) responses handled by government.

15 to 24 months for the whole process, set times for documents must be available for review, difficulties getting technical details from rocket suppliers. Can be shortened, Kistler April 97 to December 97, PER not EIS.

Legislation issues: Commonwealth environmental legislation, foreign affairs impacts, etc. State and territory, environmental legislation, none for Christmas Island. New pending Commonwealth space activities bill. Not just consider normal operations, but consider the impacts of failures.

Need also to consider global issues, space debris. Currently 8500 greater than 10 centimetres, 100,000 greater than 1 cm, up to 54,000 km/h. 600 active, 3500 spent stages and satellites, 3900 fragments, approximately 500 mission related.

Talk 3: University of NSW, Mr Jeffrey Candilaro, Jonathan Ingles (Canadian exchange student).

Space frontier society (SFS) chapter, amateur satellite project by students. Basic LEO UNSW experiment satellite (blue sat). $500 price, first to launch Amsat. University of Melbourne launched amateur satellite in the 1960s. Looking for industry sponsors, within three years will be set up to do one satellite per year. Researching previous projects etc, begin by mid August. Preliminary conceptual design. Geometry 30 cm cube, 10 kg, solar cells on the outside, gallium arsenide cells too expensive, UNSW silicon cells are an option, higher efficiency, degradation unknown, unqualified. Higher risk, maybe commercial power system, nickel cadmium batteries. Communications amateur packet radio, 400 MHz down, 140 MHz up.

Semi autonomous ground station. On-board controller. Attitude, magnetic torquer, passive permanent magnets, hysteresis rods. Payload, experiment, infrared data transmission, camera, inflatable balloon, etc. Launch piggy-back, looking for a free launch, seeking sponsorship from industry.

Talk 4: Government Minister

While the delegates milled about outside enjoying the coffee and danishes, the organisers busily moved about in the conference room. The minister was to talk next and his press secretary insisted on rearranging the podium furniture with the microphone faced more to the left so that the TV cameras could get a view of the Minister from his right side. The overhead projector had to be removed as it spoiled the shot. The Ministry people quickly took the projector away despite the protests of the next speaker who would need it for his presentation. Rather than showing the conference logo the screen displayed photographs of the Minister which was not replaced until the Minister himself arose to speak. A man clearly already older than the one in the photograph. Slowly, the audience gathered again with the second and third speakers on the stage but the Minister himself did not appear until moments before the conference recommenced. In fact it seemed it may have been delayed 10 minutes for him to arrive fashionably late.

In a clear and concise voice showing his clear oratory skills, the Minister made his presentation without any obvious hint that in fact he was reading a speech prepared by staff. All the while the screen behind the Minister showed a government coat of arms and the Minister's name.

Video was played showing the Minister at Woomera, Kistler groundbreaking, showing the Minister discussing Woomera and discussions with Electro-Optic Systems (EOS). Sales tax 22%, exemption for launch vehicles and satellites. 1997 government agreement to replace previous agreement with Russia, confident it will be concluded later this year.

The delegates quietly listened to the presentation by the Minister. Despite the media camera and microphone people arranged around about the floor, in front of the podium and down the aisles.

Talk 5: Astro Tech (USA), Mr George Baker

In business 15 years, subsidiary of SpaceHab since February 1997. Commercial payload processing facilities, Florida and Vandenberg, Long Beach for sea launch. Processing is the final step in manufacturing, first step of launch. Design, construct, operate and maintain payload processing. Processing includes load and unload aircraft, transport to site, security, safety, propellant handling solid and liquid, communications. In Florida separate, hazardous and nonhazardous. Other sites get together in compartmentalised buildings. Working with both Kistler and APSC in Australia. New area of business, sub orbital launch services, ex-NASA experts. Expected base some launches at Woomera, planned mid 1999 launch, Astro Tech, ASRI, US DOD, DSTO, University of Queensland. Partners in Pacific rim include SpaceHab Taiwan, and Mitsubishi.

Talk 6: Australian Space Research Institute (ASRI), Mr Mark Blair

High R&D start-up costs, long lead times, low levels of public and private investment. Low industry confidence, international competition, politically restrictive market. Ausroc (rockets), Australis (mini satellites), scram jet (Queensland University), Sighter (ex RAAF rockets for education). Now developing Ausroc 3, scheduled mid 2000, 8.7 m/s, 100 mm wide, 1600 to 1700 kg, payload 150 kg to 500 km altitude. Carbon fibre composite body and fuel tanks, trust vectoring attitude control. Scramjet, flight tests planned in Woomera in mid 1999 on sounding rocket provided by Astro Tech, only scramjet outside Russia. Australis, Amsat – NA design. First, 15 kg satellite, launch expected in 2000, multi-spectral imager, GPS module, packet coms. Sighter, ex RAAF rockets, 1000, stored at Woomera, for educational launches, 10 kg to 7 km, single stage, two weeks launch periods per year. Looking for industry support, in-kind goods and services.

Talk 7: Kistler Aerospace, Mr Robert Wang

played standard company video. First risk is technology. Have done drop tests, with a parachute each 165 feet. All 6 parachutes equal the size of 3 football fields. There will be an air bags drop test in 60 days. 1st set of tanks are finished. 70% of the 1st vehicle is complete. Will send to Australia end 1998, and

launch 1st quarter 1999. Looking for $800 million, have $400 million so far. 2nd risk is finance. Board includes former chairman of Boeing, McCall, former chairman of the FCC, and others. 3rd risk is regulatory. Test flights 1st quarter 1999, commercial flights 2nd quarter 1999. Plan to start Nevada test site 2000. Prefer to have 2 sites for flexibility.

Talk 8: Arianespace, Mr Richard Bowles

standard presentation. Ariane 4, 96.9% availability. Asia-Pacific satellites only, 17% failure. Order book, 40 satellites, $3.4 billion. Will continue using Ariane 4 and Ariane 5 until 2003.

Talk 9: University of Queensland, Dr Allan Paull

scramjet facility. Shop test facilities, Mach 8 to Mach 22 (orbital speed). New facility next year, 50,000 km/h, aero braking tests. Testing to save weight required for braking shield. 1st scramjet was 1993. Newest just to be tested. Currently negotiating to do some tests with Astro Tech.

Talk 10: The Aerospace Corporation, Mr David Beardon.

Assessment of space-based hyper-spectral imaging architecture alternatives. Reduced budgets. Need cost efficiencies. High resolution required. Less on-board storage, shorter time to download images. Single frequency, multi-spectral (2 – 20), hyper-spectral (100+ bands). Failure of Lewis. High resolution. Failure early-bird and cancel Clark. Concept analysis. Mission requirements, system architecture, orbits, payload, satellite sizes, spacecraft design, configuration, launcher, costs. Broadband satellite relay, payload 2005, 682 Mb/s using Teledesic and 155Mb/s using Celestri. Compared with store & forward technique. Problems, Teledesic etc, designed for fixed ground sites, not moving satellites in orbit. Teledesic give 30% not covered, Celestri 60% unavailable. 300 to 700 kg launch mass, 6 to 7 satellites, best orbits to get coverage location on earth every 12 hours, revisit. Next step, consider alternatives. Such as GEO. Or sit inside a constellation and use optical ISL (look like other LEO com sats). Future TDRSS.

Talk 11: Johns Hopkins University, Alice Bowman

MSX spacecraft. Track missile launches. 9 telescopes, infrared to ultraviolet, narrow and wide. spectrographic images. Infrared and UV mapping of sky while waiting for launches to track. Study Aurora, clouds, stellar occultation, ozone mapping. Polar mesospheric clouds form in mesosphere, above latitude 50°, in local summer, affected by methane and CO2 emissions, measured to monitor greenhouse.

Talk 12: Spot Image (Australia), Mr Carl McMaster

changing scene. More private sector. Relaxed government restrictions on resolution. Technology improvements. Market acceptance. Merging with aerial photography. Existing government funded such as Landsat, Spot, IRS, greater than 6 m resolution. Future private expected 1 to 3 m resolution. Customers want product quicker, disaster situations, floods, fires, etc. Currently only used after-the-fact for later analysis. Spot 3 failed 1996, Spot 4 launch March 1998, Spot 1 and 2 still operating. Spot maintain swath width 60 km, while reduce resolution less than 3 m. Other systems 1 to 3 m resolution, but only 8 to 10 km width. Spot 5 expected end 2001. In future, 2003+, Spot 3S, system of cheaper sets in a constellation. 20 ground stations, one at Alice Springs, one at Hobart. For 3S maybe use Artemis, ISL, and single or small number of ground stations. Maybe use on-board processing. Landsat to have some much cheaper products with Landsat 7, March 1999, will affect the whole industry.

Talk 13: Auspace Ltd, Mr Roger Franzen

Aries remote sensing satellite. Polar orbit sun synchronous, 500 km, 450 kg, 2.5 m x 1.2 m x 1.2 m. Landsat 20 m, seven bands, 1 m band?. Aries 30 m?, hyper-spectral, 400 nm to 2500 nm, 16nm bands, SNR 400:1. 15 km swath, +/-30° axis pointing. Want to use a proven bus, three currently shortlisted. Launcher choice Euro rocket, Cosmos, Athenia, Taurus, Kistler? Control, tasking, archive from Australia. Investment structure, Aries company, owned by Aries consortium and Exploration consortium. Data for surface mineralisation, soils, geological maps, agriculture, crops, crop ID, health, forestry, species ID, geochemistry, green/dry. Environmental, land, water, vegetation. Water, maps, quality, wetlands maps,

climate, variation.

Talk 14: China Academy of Surveying and Mapping, Prof Hang Qingpu

using remote sensing for flood prediction, monitoring and assessment. Non-structural measures. Fast accurate info on flood, preliminary evaluation in 1 to 2 days. Integrate with other information systems, GIS, GPS etc. Coordinated distribution distributed information system. Hardware and software easily maintained and upgraded. FPIS, flood prediction information system.

Talk 15: Radarsat, Canada, Mr Robert Tack

formerly connected with RHEOSTAT and Spot Image. Radarsat private company established 1989. Radarsat 1 1992, Radarsat 2 2001. Flexible imaging and viewing angles. Expected use Internet for data transfer for 90% of products within one year. 5.5 hours turnaround, taking picture, processing and deliver.

Talk 16: Earthwatch Inc (USA), John Douglas (Adelaide Australia)

formed 1995, Ball, Hitachi, Telespazio, Orbital Sciences, Datron, etc. Earlybird failed. Quickbird 1 and 2 late 1999. Digital Globe services, data provision, data brokerage, both aerial and satellite imaging. Multi-spectral, 4 band, 0.82 m, 20 km swath, flexible various modes, stereo, etc. United States, Russian launch. Digital Globe, database of data from various sources, accessed via Internet to pay and download data on demand.

Talk 17: Asia-Pacific Aerospace Consultants, Dr Bruce Middleton

Asia-Pacific's largest GEO market. In past only companies supplying satellites and launches in Asia: Russia, China, India. Economic slowdown, sats deferred. Expect 12 satellites per year until 2005, 10% to replace old. Three Japanese companies plan manufacturing sats by 2005: Mitsubishi (MELCO), NEC (LEO), Toshiba. Korea plans to build future Korea sat replacements, Hyundai started, but stopped due to economy. Insat, first Indian built, 2A onwards. China. Australia, subsystems, LEOs Aries and Fedsat. Malaysia, UOSat build micro satellites. Singapore, Nan yang, payload for UOSat, future microsatellites. Taiwan, ROCsat 1, RS, TRW built. Thailand, plans slowed by economy. Launchers: China, Long March, first commercial 1990. Japan, H2A models, Rocket Systems Corp, H2A using some US imported components, 4-7.5 tons to transfer orbit. India, GSLV, first early 1999, launched from Sir Hari Kota, 50 km north of Madras, 13° north, 1 to 3.5 tons to GEO. LEO launchers: China, LM2C, 3.2 tons to LEO. Russia, Sovodny, West Sakhalin, 51.5° north, START 1, two so far. India, PSLV, 2.9 tons, 200 K, first 1993, operational 1997. Australia, Kistler K-1, first expected 1999, contract for 10 Globalstar. Japan, J1, 900 kg to LEO, too expensive, IHI and Nissan J1 upgrade, 2002, $14.5 million per launch.

Talk 18: Department of Industry Science and Tourism, Mr Elio Grohouaz, Launch Licensing in Australia

UN space treaties, apply to governments, not corporations, so not commercial, 5 treaties. Outer space Treaty. Liability Convention. Article 11, surface of the earth or in the air, government launching, Absolute Liability. Article 111, fault based liability for damage in space. Overseas launch certificate, for launches procured overseas. Exemption certificates, experimental sounding rockets etc.
Non-recurring cases: Space Licence; Launch site approval; Vehicle Type approval; Operations Approval.
Recurring cases: Launch permits, launch by launch or group of launches; insurance; payload clearances; licence fees; approved operational parameters.
Launch site approval includes: land title, environmental, study plans procedures, construction permits, DA, BA, commissioning tests.
Vehicle type approval includes: design and manufacture, design and manufacture do not comprise compromise safety, national interests, international obligations, operator submits specs and test results for analysis.
Operations approval includes: risk and hazard analysis, worker health and safety, documented safety procedures, emergency preparedness, hazardous materials, environmental management, incident investigations, approval of radio frequencies.
Launch permits include: evidence of third-party insurance, licence fees, nature of payload identified and

comply with policies, launch times, dates, trajectories, no hazardous or unauthorised materials, country of origin register payload with UN.

Question: Arianespace: will safety requirements apply to Australian satellites on other launchers? Commercial implications? Answer: DIST, can't regulate overseas launches, but potential liability of a "launching state", so require insurance, separated overseas launch permit requirements.

Question: Insurance? Answer: DIST, maximum probable loss, no ceiling (USA has ceiling of $800 million)

Talk 19: Ward & Partner's, (Australia), Mr Michael Davis

space and national needs. So far industry uncertain, fragmentation, shortsighted governments. Need to learn from the past, Synergy space and non-space, understand benefits.

Talk 20: QUT – Centre for Satellite Navigation (SCSN), Mr Grant Wensor

SCSN connected with: Fedsat, Ausroc (ASRI), Amsat (ASRI), Sighter, Education. SCSN aim to match funding for novel projects, GPS applications, including tracking, navigation, positioning.
Examples: Brisbane Council, 600 buses. BHP, 16 coal barges, comms via Inmarsat. Queensland rail, 900 trains. Vic trains, 600 trains. Can mills, 45 trains.
Navigation: aircraft, luxury cars, marine pilots, bushwalkers and boaties.
Positioning: precision farming, Case tractors, autonomous control of mine vehicles, drilling rigs.
Fedsat: $50 million, providing satellite tracking GPS, on-board computer. For Mach 25, LEO orbit, need MIL grade GPS receiver, requires US export permits.
Ausroc, launch impact prediction.
Amsat, 15 final year students, ASRI, AMSAT-NA, include GPS.

Talk 21: FEDSAT, Dr Brian Embleton.

Cooperative Research Centre for Satellite Systems. Seven year funded Centre. FEDSAT is one project. Utilising existing funding mechanisms. Spending less on admin and more on projects. Smaller, cheaper, faster. Growth areas include communications, remote-sensing, defence. Small sat program, quicker realised, less expensive, focus on technology. Launch cost average US$259,000 per kilogram. FEDSAT will include GPS receiver and magnetometer from USA, international program, proven platform. FEDSAT platform, Space Innovations Limited, SIL (UK), three axis stabilised with boom for magnetometer. Develop and qualify payload instruments in Australia, where possible. Magnetometer, explore effect of solar max on magnetic field.

Question: developing the platform in Australia? Answer: Maybe in future, now concentrate on value added payload end.

Question: SIL platform has to squeeze the payload in, Australis is modular? Answer: SIL includes power system etc which is required now.

Talk 22: CRC for Satellite Systems, Dr Mike Miller

(Prof, Deputy Executive Director, CRCSS, Prof Telecommunications University of South Australia)

To deliver a new, sustainable advantage to Australian industry and government agencies involved in services based on application of small satellites.

- Space science: University of Newcastle, New Mag magnetometer experiment, ionosphere and atmosphere studies using GPS, QUT, Latrobe.
- Satcoms: Ka and UHF techniques, modems, coding and multiple access, ISL, Ka band propagation.
- Internet and ATM services via LEO satellites: protocols, data acquisition, traffic control for packet-based and broadband switching.
- Advanced earth terminals: transportable Ka terminals, smart TT&C ground stations, PALACE buoys for marine science.
- Advanced RF subsystems: new antenna structure for Ka band, space qualified gallium arsenide MMIC's, deterioration of gallium arsenide in space.

- Hyper-spectral remote-sensing (ARIES): atmospheric modelling, mapping, interpretation.
- Satellite systems: tracking (GPS), high-performance computer payload, solar cells.
- Research training program: 30 PhD students in three nodes.

Talk 23: Optus, Dr Gordon Pike, Manager Satellite Planning.

Optus satellites near end-of-life, A2 1999, A3 late 2002, B1 end 2005, B3 end 2008. System at capacity. Traffic emphasis on broadband. 500 MHz is allocated to Australia in the BSS band, can't use due to antiquated technology assumptions. New Optus C1, joint with ADF, will replace A3, expanded coverage into Asia. ADF, UHF, X, Ka, terminals and operations and maintenance. ADF currently uses Leasat 5, 156° east, EOL 4 to 5 years. Optus C1 coverage will go from NZ up to Korea plus Japan and Hawaii. Expect to sign contract December 1998, on orbit 1 April 2001. In future consider B1/B3 replacements to start planning 2004. Propose Australia lead the charge to try to change UN treaties.

Talk 24: PanAmSat, Mr David Ball

PAS4/PAS7 co-located 68.5° east. G4 in super synchronous drift, communications work okay, but no attitude control, will try again later. Internet over satellite is a growth area. Asymmetric, 4:1. Multicasting/broadcasting, data push. Combine IP and MPEG video distribution. e.g. CNN website with CNN TV.

Talk 25: SS/Loral, Mr Howard Kirker.

VP Sales. 1997 sales US$1.44 billion, order backlog US$1.8 billion.

Talk 26: KITComm (Australia), Mr Steve Morgan (USA)

AT&T One Rate, $0.25 per minute home and office, AT&T Wireless Digital Mobile $0.11 per minute. 21 satellites in three planes. 1.6 GHz L band two-way. 2.5 megabits per second, 4 MB messages per day per satellite. 200 km orbit. Fully automatic. Kitcomm staff, customer care, keep control of mobiles. Regional operators and partners. Licence fees, revenue sharing. Service providers, recurring communications fees. Kitcomm revenue, licence fees, revenue sharing, recurring communications fees, royalties on terminals. For example, shipping containers cost US$2000 basic, or US$17,000 to $25,000 refrigerated, and insurance cost on a $3 million load of perfume is $21,000. Initially it will concentrate on non-US, in case of regulatory problems in the USA.

Talk 27: Consultant (USA), Dr James Stuart, CEO Kitcomm

Next Generation Satcoms: Network Architecture, Technologies, Space Systems.

There is a current boom in LEO, quick access to global demand (deregulation), satcom technology, bullish markets. Satellites just part of communications network, integrated. In the early days of market, everything works, but eventually sort out to best techniques. Spectrum will be a limiting factor in future, will drive market share in the 2nd and 3rd generation. For global call, multi-hop wastes precious up and down spectrum. Better to use up and down spectrum once and use inter-satellite links.

Little LEOs have gaps, good for store and forward. Big LEOs and GEOs have global coverage. Ka band data systems, broadband V band systems on the horizon.

Predicts there will be design changes in the next three years, there will be a shakeout, resolved in 10 years. Expect photon processing, solar arrays bigger and better, RF bigger antennas, spots reuse spectrum, future systems large apertures. Moore's law, performance/price doubles every 18 months, will likely hold for next 20 years. Winners have high market share, service shakeout. 30% market share and low-cost supplier dominates. Scalable open architectures, rapid tracking of market demand, new deployments less than two years, replace/upgrade less than 5 years.

Next generation GSOs: the future continues to improve, inter-satellite links, interlink hybrid MEO/LEO/Aerostats. Revolution will be GSO cluster, open architecture for adding new subsats, each with 30m dish, inter-satellite links, station keeping together, formation rotates once per day around central switching satellite. Interconnect all frequencies, incremental, scalable, graceful introduction.

Little LEOs: differentiate market niche, ground relay (satellite on ground), agile multi-frequency (C,Ku,Ka) interoperable terminals, inter-satellite links, larger constellation and smaller satellites. Interlinked into hybrid, GEO, etc. consolidate common platforms, multi-payload constellations, competitors share constellation. Little LEO as payload on other LEO, new services value-added, concentrators bypass, trunking, global access, download, etc.

NEXT WAVE: system architect, not satellite designer, distributed, adaptable, short lifetime. Micro nanotechnologies, MEMS devices (beyond IMU) ready, Fresnel and steerable antennas. 3D multi-shell, multi-function constellations. Virtual (cluster) satellites. Aerostats, very low stationery, multi-payload. Micro nano satellites, distributed interconnected swarms, golf-ball satellites, thin sats (large in 2D, thin in 3D).

Talk 28: Deacon Communications (Australia), Mr Chris Deacon

Ellipso, was first to file FCC 1990. Mobile phones less than $0.50 per minute, less than $35 per month. Mobile Comms Holdings Inc. Lockheed Martin ground segment, Boeing satellites, Harris payload, Israeli Aircraft attitude control, Spectrum Astro power, A?? Eng solar arrays, Arianespace launch. Satellites in elliptical orbit, bent pipe, ground terminals and network. Ground stations C band and Ku band, terminals S band and L band. Two ground stations in Australia, one at Bundaberg, one on West Coast.

Borealis, to serve northern hemisphere. Concordia, equatorial orbit, equatorial and southern hemisphere, global coverage, 16 satellites. Tropic of Cancer separates two coverages. Borealis in two phases, five satellites each. Phase 1: sun synchronous retrograde 7846 by 520, highest capacity in the northern hemisphere, daylight hours. Phase 2, Concordia, equatorial six satellites, tropical, subtropical, and southern hemisphere, 7800 km, circular. Each satellite 61 beams. APTS= always point to Sun, travelling apogee. Concordia upgrade: extra capacity midday. Borealis upgrade: additional polar plane. “Global” but limit coverage to south tip of New Zealand approximately 40° south. Capacity tailored to population by latitude, peak coverage in peak usage daylight hours. Minimum elevation angle tailored, better in populated areas than Iridium, etc. Initial deployment and initial capability, not full, expected year 2000. Three axis stabilised, 750 kg, seven-year design. Started manufacture of the first two, June 1998, first launch mid 2000, 2002 for full network. Voice, non-voice, data, paging (indoor) dual mode. GSM voice, PCS interoperable, STU3, trunked radio. Data, paging, 9600 bps store and forward, broadcast data, options for internet, X.25, etc. CDMA, L3 Communications.

Talk 29: Surrey Satellite, Dr Wei Sun

Produce micro and mini satellite platforms. 150 staff, 50 university academics, staff and students. Surrey Satellite Technology Ltd, commercial arm of Surrey Space Centre, University of Surrey (UoS). Market revenue used in teaching and research. Pioneered microsatellites 1978 to 1998. Five months to build, long life, affordable. Large = greater than 1000 kg. Small= 500 to 1000 kg. Mini= 100 to 500 kg. Micro= < 100 kg. First mini sat 350 kg, launch April 1999. Built and launched 14 micro sats, UOSAT1 1981. Also do ground station and mission control centres for micro sats. Modular design. Contract with NASA for rapid satellite acquisition program, select bus from a catalogue and deliver satellite it within 18 months. Applications include store and forward email, imaging, science payloads. Propose 7 satellite network for disaster monitoring, image any site once a day. Need low-cost launches, so far using piggy back. Mini sat, UOSat 12, launch April 1999, on Russian SS-18 ICBM, modified to Dnieper launcher, Baikonur.

Future plans:

- Micro sats, science, ELINT, altimeter, 30m resolution multi-spectral, 15m resolution pan chromatic.
- Mini sats, 2.5 m resolution EO (2000), light SAR, science, tech, civilian and military.
- SNAP1, 2 kg, nano satellite.
- Hybrid rocket motor research, 400 N thrust. Planned to use mini sat to the moon, GEO transfer orbit, then hybrid motor to orbit the moon, budget of £15 million.

Talk 30: Macquarie Bank, Mr Lex Geddes.

Financing space projects. Equity, money at risk, hardest to get, expect a high rate of return. Project debt, including vendor finance, cheaper and easier to get. Other, hybrid/structured, tax based, leasing, etc.

Factors include: perceptions, main issue, perceived risk, perceived market. Nature of project. Project participants. Project phase, existing, new, development. Business plan, key to debt, schedule, market share, pricing, revenue. Debt, depends on assets and cash flows. Guaranteed. Recourse, future assets, cash flows. High yield, mostly USA, vendor financing. Hybrid/structured: generally tax based element, leasing, domestic or cross-border, shift risk and benefits to lessor, for example start-up, in tax loss, can't benefit from depreciation, write off, allow to share with lessor. Cross-border advantages of different tax systems.

Talk 31: Gadens Lawyers, Craig Powell, Ms Frances Richards

Environmental Impact Assessment, state and federal. Native title. Space Activities Bill, concern about the definition of related party. Concern about range safety officer having appropriate qualifications. Concern about criminal liability. Concerns about ministerial power and rights to challenge.

Talk 32: J. & H. Marsh and McLennan (UK), Mr Brian Moore.

Insurance brokers. 1986 was a bad year, all launch failures, including space shuttle. Huge growth in space industry since then. 1965 to date, insurance $6 billion, claims $4.5 billion. Now there are more insurers, greater capacity, lower premiums. 1998, not so good so far. Important to get insurance sorted out early on in the program.

Talk 33: Vanguard Space Corporation, Dr David Scott

On-orbit servicing & repair. Could do with available technology. Rendezvous, docking, combined vehicle operations, remote-control. Recovery, even de-orbit.

Talk 34: Micro-gravity Corporation (USA), Dr Allen Ross.

New business depends on space access. Expect cheaper launch solutions in the next 24 to 36 months. Once infrastructure available, new business in advanced materials, biological, fluid mechanics, etc. Two elements required: communications and transport.

Talk 35: Orbital Debris, NASA, Dr Miriam Baltuck

LDEF, long duration exposure facility, was in space six years, 32,000 impacts, half artificial, all less than one centimetre. See website: www.jsc.nasa.gov/debris/intro.html. LEO 200 to 400 km: debris can last a month. Higher 400 to 900 km: debris can last years or centuries. GEO stationary could be millions of years. 0.01 or less results in surface pitting erosion. 0.01 up to 1, some damage. Greater than 1 cm could be catastrophic. Hard and expensive to shield against greater than 1 cm. In GEO the problem is an order of magnitude less. Solar maximum can reduce time for debris to de-orbit by one or two orders of magnitude. In 70 flights of the space shuttle, 60 windows had to be replaced.