IAC-10-B3.8.-E7.7.6

THE INTERNATIONAL SPACE STATION AS A "TRADING POST IN OUTER SPACE": A VIEW FROM EUROPE

Robert P. Veldhuyzen
European Space Agency (ESA), retired, The Netherlands, robert@veldhuyzen.eu

Upon closer consideration, there are many similarities between the built-up and operations of a Dutch Trading Post ("Factory") in 1609, initially located at Hirado on the westernmost tip of Japan, and moved in 1641 to Deshima (Nagasaki), and the International Space Station (ISS); the similarities between these "outposts" are highlighted, together with the many challenges which had to be faced by the sponsoring parties and the "outpost" occupants. A brief overview is presented of the legal framework developed for Space Station cooperation, which is featured by an innovative and unique three-tier structure, together with the main reasons for this approach. In addition to summarizing the main European contributions to the International Space Station, a comprehensive overview is presented of the large variety of other contributions which Europe has developed for the Space Station on the basis of barter agreements with Space Station partners, primarily in the context of offsetting bilateral and multilateral obligations resulting from the Space Station cooperation. This omni-presence of European built hardware is a good illustration of ISS serving as a unique outpost for "trading space". The benefits which Europe and the ISS partnership have derived from this wide-scale use of barter arrangements are addressed, together with some critical remarks and "lessons learned" for ongoing and future large cooperative ventures in human spaceflight.

I. THE INTERNATIONAL SPACE STATION IN A HISTORIC CONTEXT

Upon close consideration, there are many similarities between the International Space Station (ISS) and the built-up and operations of a Dutch Trading Post ("Factory") in Japan more than 400 years ago (1609), initially located at Hirado on the westernmost tip of Japan, and moved in 1641 to Deshima (Nagasaki):

- The Trading Post was located on terra firma at a distance of more than 9,000 km from Amsterdam ("as the crow flies"), whilst ISS is orbiting at an altitude of only 380 km above the earth in outer space, but with a velocity of 28,000 km/hour; both ISS and the Trading Post are thus located in a completely different world or environment as compared to their "home base" and only accessible through journeys requiring extreme efforts in resources and ingenuity, whilst exposing the explorers to important risks;
- For the Trading Post, the travel time and related hardships were the determining factors for its characterisation as outpost: from the initial "reconnaissance" fleet of 5 sailing ships which left Holland in June 1598, only one ship (bearing the appropriate name of "De Liefde" (Love)) arrived almost 2 years later at its destination in Japan in April 1600 with no more than 25 out of its crew of 100 alive; for ISS, it is not the travel time to and from earth (less than 3 days), but rather the significant technological and financial challenges to transport humans safely in space and back to earth, which also make ISS qualify as a true outpost;
- Both the Trading Post and ISS have only been made possible by organisational structures, which one could characterize in both cases as being of a revolutionary nature: in the case of the Trading Post, this was the "United East Indies Company" (or better known as "VOC"), a true multinational company avant la lettre, and in case of ISS a world spanning, long-term international cooperative framework established between fifteen governments, on the basis of genuine partnership; in both cases, legal instruments played a key role: for the Trading Post this was the "Trade Pass" which was negotiated by one of the VOC international staff, the British navigating officer William Adams, and issued to the Dutch by the Japanese Shogun Tokugawa Ieyasu on 24 August 1609, stating that *"Dutch ships are allowed to travel to Japan, and they can disembark on any coast, without any reserve. From now on this regulation must be*

observed, and the Dutch left free to sail where they want throughout Japan. No offences to them will be allowed, such as on previous occasions. Signed the 25th day of the 7th month of the 13th year of Keicho, Tokugawa Ieyasu"; for ISS, the legal instrument is the "Intergovernmental Agreement (IGA)" concluded between the governments of Canada, 11 member states of the European Space Agency, Japan, the Russian Federation and the United States of America, which provides the framework for the design, development, operation and utilisation of this largest and most complex technological project undertaken by mankind (see further in Chapter II);

- In view of its outpost nature, the Trading Post, at its ultimate Deshima location (an artificial island with a 520 meter perimeter and only connected to Japan through a single well guarded bridge) was staffed by a limited number of occupants (10-30), headed by a formal Chief ("Opperhoofd"), who had to be exchanged once per year, as stipulated by the Japanese Shogun; such exchange was made at the occasion of the annual visit by a fleet of VOC trading ships (the number varying between 2 and 7, depending on the "economic climate") which sailed at the end of June from Batavia (presently Jakarta, Indonesia) to Japan in 5 – 8 weeks with the south-western monsoon; after the trade-season from mid-August to end-October, the ships sailed back to Batavia on the north-eastern monsoon, returning the outgoing Chief and other staff not required outside the trade-season; thanks to modern technology and automation, the ISS outpost needs only to be staffed with 3-6 occupants, but they equally are exchanged at regular intervals the schedule for which is also determined by natural phenomena, namely in this case the physiological limitations of human beings in weightlessness rather than the previously mentioned monsoons; thus, ISS crews, headed by a designated ISS commander, are organised according to so-called Increments of 6 months duty cycle on-board ISS following which they are exchanged by a new crew; depending on the ISS crew seize, 2 respectively 4 space "ships" (with 3 places each) are required for this semiannual crew exchange process, in addition to 4-6 automated cargo ships for re-supply of ISS, where outer space does not provide (yet) for means to support humans with their basic requirements;
- Besides its principal trading function, which the Trading Post in Japan performed in a very profitable manner for its mother company VOC, it equally developed into a unique and privileged technological, scientific and cultural bidirectional transfer institution between Holland (the Western World) and Japan (e.g. illustrated by Rangaku or "Dutch (Western) learning", the body of knowledge developed by Japan through its contacts with the Dutch traders in Deshima); it is considered that ISS today very much also fulfils such function as transfer institution besides its principal function as outpost in space for research & development and preparation for future human exploration, whilst the trading function of ISS will be developed in further detail in Chapter IV;
- Finally, the good functioning or "maintenance" of both the VOC and ISS outposts required what can most appropriately be described by the modern terminology of Extra-Vehicular Activity (EVA); in the case of the VOC Trading Post, once per year the Chief was obliged to leave the confinement of the Trading Post and undertake a courtesy visit to the Japanese ruler (Shogun) located in Edo (today's Tokyo); this journey, for which preparations started after the sailing ships had left the Trading Post for Batavia in November of each year, was implemented in the next year February – May period where it covered a voyage of not less than 2,000 km; it had as primary objective to put in evidence the gratitude of the VOC for the extra-ordinary and exclusive position which it enjoyed in Japan (amongst others expressed through the handover of valuable presents to the Japanese rulers as well as the reporting on major developments in the Western world, where the Japanese population was kept fully isolated by its rulers at the time); equally challenging in the case of ISS, are the walks (EVA) in outer space outside the confinement of the pressurized ISS modules, for regular maintenance/repair and upgrading activities, as well as for specific utilisation and research objectives.

Thus, despite the 400 years gap between the VOC and ISS outposts, many challenges which had to be faced by the sponsoring parties and the occupants were remarkably similar in nature.

II. THE INTERNATIONAL SPACE STATION (ISS) LEGAL FRAMEWORK

The ISS programme is not only the most ambitious and expensive space project ever undertaken in a cooperation mode amongst 5 Partners (the governments of Canada, 11 ESA member states (constituting the "European Partner"), Japan, the Russian Federation and the United States of America), it also features the most comprehensive long-term international cooperative framework ever developed to govern a space project conducted on the basis of "genuine partnership". This framework was developed to respond to the particular needs of the ISS programme and contains many "state of the art" provisions developed over more than 12 years, which form together what is generally referred to as the "legal regime for ISS cooperation".

The legal regime is featured by an innovative and unique three-tier structure, setting forth the rules for ISS cooperation, as follows:

1) a multilateral State-level Intergovernmental Agreement ("IGA"), having the character of an international treaty, and providing the necessary political "binding force" to a programme that is vulnerable due to its large size and long life-time;
2) four bilateral, largely identical, Memoranda of Understanding ("MOU") between NASA and each of the other four Cooperating Agencies, thus creating a sort of "hub and spokes" system for the implementation of the detailed design/development and operations/utilisation aspects of the cooperation, but also providing for the establishment of the multi-lateral bodies for the management of the cooperation; and
3) bilateral Implementing Arrangements ("IA") between NASA and each of the other Cooperating Agencies, for detailing, as required, the modalities, terms and conditions for the implementation of obligations stipulated in the MOUs.

The reasons for this approach and, in particular, for relying on an intergovernmental agreement with explicit Governments' endorsement of the cooperation were:

a) the significant funding needs, reaching multi-billion dollars level for each Party and making a multi-year financial commitment essential;
b) the duration of the project which, in the IGA, is open-ended; and
c) the fact that many aspects of the cooperation touched on issues which were over and above the prerogatives of any of the Cooperating Agencies concerned (e.g. the exercise of State's jurisdiction and control onboard the different modules of ISS, liability aspects).

Finally, and also as an introduction to Chapter IV below, Article 15.5 of the IGA should be specifically recalled here which stipulates that "The Partners shall also seek to minimize the exchange of funds in the implementation of Space Station cooperation, including through the performance of specific operations activities as provided in the MOUs and implementing arrangements or, if the concerned Parties agree, through the use of barter".

III. THE ISS AND THE MAIN CONTRIBUTIONS BY EUROPE

It is almost 2 years ago in 2008 that the ISS community celebrated an important milestone, namely the tenth anniversary of the start of the actual build-up of the International Space Station with the lift-off of Space Shuttle Endeavour for its 12 day mission to deliver NASA's "Unity" module and connect it to Russia's Zarya control module which was already orbiting earth since its launch on 20 November 1998 by a Russian unmanned Proton launcher. Since that historic date, the assembly of ISS has progressed considerably and can today be considered as largely completed with appr. 90% of its ultimate mass (422,000 kg) and 85% of its pressurized volume (1,000 m3) in orbit; this was supported by 102 transport missions with crew and/or cargo and 164 spacewalks (EVAs) with a total time of more than 1,000 hours. The ISS has achieved with the four huge solar arrays its characteristic shape and full power generation capability, and covers now an impressive 110 x 51x 20 meters. Only 3 further assembly missions (2 Space Shuttle and 1 Proton) will be required to transport the remainder ISS hardware into orbit for achieving the long awaited ISS "assembly complete" milestone.

For Europe and ESA, the year 2008 was the culmination of more than 13 years of development work with the launch of its two main contributions to ISS:

a) the Columbus laboratory, a pressurized research module which is permanently attached to ISS, was launched by Space Shuttle mission STS-122 from Kennedy Space Centre on 7 February 2008. Its key physical parameters are a length of 6.8 meters with a diameter of 4.5

meters, thus providing an internal volume of 75 cubic meters with a maximum on-orbit mass with payloads of 21,000 kg. Columbus permits multidisciplinary research in the fields of material science, fluid physics and life science through its internal payload facilities, whilst its external payload accommodation can host experiments and applications in the fields of space science, earth observation and technology. A comprehensive research programme is in full swing since its launch and subsequent commissioning;

b) the Automated Transfer Vehicle (ATV), a servicing and logistics vehicle to transport appr. 6,000 kg experiment equipment, spare parts, food, air and water to ISS, as well as propellant, whilst also having a propulsion system which permits to maintain ISS in its proper orbit during its 6-month attached phase to ISS; ATV, with a launch mass of 20,750 kg, a length of 9.8 m, diameter of 4.5 m and solar array span of 22.2 m, represents one of the most complex and largest spacecraft ever developed by Europe, and its first mission ("Jules Verne") started on 9 March 2008 on top of an Ariane 5ES launcher from the European launch base Kourou in French Guyana; the mission was a complete success, with the demonstration of all key ATV functions, including a fully automated docking to the Russian segment of ISS and several ISS re-boost operations, whilst it ended on 29 September 2008 with the planned re-entry in the earth atmosphere and fulfilling its final function of ISS trash disposal; the Jules Verne mission will be followed by at least 4 more ATV missions, the second one ("Johannes Kepler") being presently readied at the European launch base Kourou for launch in November/December 2010.

Whilst not being a contribution in the material sense, this overview of main European contributions to ISS would not be complete without mentioning the European Astronaut Corps, comprising a team of trained and qualified European astronauts to participate in both ISS assembly missions as well as to enable full use of the right for Europe to provide crew on-board ISS; the Corps presently comprises fourteen members, including six new recruits in 2009 who recently completed their basic training; twelve European astronauts have stayed already for shorter or longer periods onboard ISS, three of whom at two occasions. ESA astronaut Frank de Winne served in 2009 as member of the first permanent ISS crew of six and as the first European commander of ISS, a function which so far was only exercised by US or Russian astronauts. ESA Astronauts Paolo Nespoli, Roberto Vittori and Andre Kuipers are presently assigned to and training for ISS missions in the 2010/2011 time frame.

IV. THE ISS AS A UNIQUE OUTPOST FOR "TRADING SPACE"

Whilst Chapter III covered the main European contributions to ISS, as stipulated in the IGA and MOU, Europe is present on ISS in many other areas; actually, Europe, perhaps more than any other ISS Partner has made full use of the earlier quoted IGA article 15.5 in order to discharge its obligations and requirements resulting from the ISS cooperation through the provision of goods and services, without exchange of funds; where this equally applies, albeit to a somewhat lesser extend, to the other ISS partners, ISS has thus developed into an impressive trading post for space hardware and services between the ISS partners. In this way, the synergies of this unique cooperation have been brought to bear at a level which could not have been anticipated at the outset, but certainly sets a reference for future large scale cooperation for human space exploration.

In the following, the main additional European contributions to ISS will be listed with reference to their underlying rationale, which is in most cases that these contributions were an offset for obligations by virtue of IGA and/or MOU, but equally for additional requirements which developed over time:

a) Data Management System for the Russian segment of ISS (DMS-R): actually this was the first European hardware on ISS, when it was launched on-board the Russian Service Module in July 2000, and it has operated flawlessly since; it provides critical functions for the entire ISS, including guidance, navigation and control, on-board systems and subsystems control, mission management and failure management/recovery. DMS-R comprises 2 fault tolerant computers and 2 control posts for use by the crew; ESA has developed and provided DMS-R to its Russian partner in exchange for Russian developed hardware (Docking System units), which ESA required for its ATV development, on the basis of a dedicated bilateral agreement with the Russian Space Agency (Roscosmos);

b) Multi-Purpose Logistics Modules (MPLM, 3 units): these pressurized modules serve as ISS "moving vans", carrying up to 9,000 kg equipment, experiments and supplies to and from the Station; mounted in the Space Shuttle cargo bay for launch and return, the MPLM module is berthed to the Station using the Station robotic arm after the Space Shuttle has docked; during the connected periods of approximately 2 weeks, ISS crew can unload from and load hardware in the MPLM which has a pressurized environment (like the ATV cargo carrier); the MPLM units, with a length of 6.6 m, diameter of 4.2 m and launch mass of 13,200 kg, have been built under the responsibility of the Italian Space Agency (ASI), on the basis of a dedicated MOU between NASA and ASI, in return for specific astronaut flight opportunities for Italian astronauts and Italian research allocations on ISS, over and above the opportunities through ESA; the MPLM modules have made so far ten missions to and from the ISS; whilst strictly speaking not being "ESA" developed hardware, it is being mentioned here because the MPLM and Columbus module designs are largely identical and also share similar subsystems; in this context, ESA and ASI concluded a complementary agreement by which ASI provided ESA with the primary structure for the Columbus laboratory module, whilst ESA provided in exchange to ASI the Environmental Control and Life Support (ECLS) subsystem for MPLM; with the MPLM becoming obsolete after retirement of Space Shuttle, a modified MPLM, referred to as Permanent Multi-purpose Module (PMM), will be permanently attached to ISS at the occasion of the upcoming Space Shuttle mission STS-133, as an additional pressurized volume for scientific utilization and storage;

c) Node 2 ("Harmony"): this is a pressurized module which serves as a connecting passage between the European Columbus laboratory, the US laboratory Destiny and the Japanese laboratory Kibo; Node 2 also provides berthing ports for the Space Shuttle, the Japanese HTV transfer vehicle and MPLM, and has a base point for the Space Station robotic arm (Canadarm 2). Its structural design, like for the MPLM, is based on the Columbus laboratory module with a mass of 14,500 kg, a length of 6.7 m and diameter of 4.5 m. Node 2 was launched in October 2007 on board Space Shuttle mission STS-120 and built by ESA for NASA as partial compensation for NASA providing the Space Shuttle launch of the Columbus laboratory, on the basis of a dedicated NASA/ESA Implementing Arrangement;

d) Node 3 ("Tranquility"): this is also a pressurized module, much like Node 2, which accommodates advanced Life Support Systems and a Waste and Hygiene Compartment necessary for the permanent ISS crew of six; it also accommodates the ESA built Cupola observation module (see below); Node 3 was launched in February 2010 by Space Shuttle mission STS-130 and berthed to the port side of Node 1 ("Unity"); Node 3, like Node 2, was built by ESA for NASA as partial compensation for the Columbus laboratory launch services;

e) Cupola: this observation module provides a pressurized observation and work area for the Space Station crew, offering unique visibility in support of the control of the space station remote manipulator system and general external viewing of the earth, celestial objects and visiting vehicles; the structure has an overall height of 1.5 meters and diameter of 3.0 meters with an on-orbit mass of 1,880 kg, and features an external shutter system for its windows which provides protection against micro-meteoroids and orbital debris. Cupola was launched, together with Node 3, by Shuttle Mission STS-130 in February 2010 and relocated on the nadir facing port of Node 3. The Cupola was built by ESA for NASA, in compensation of which NASA provides for the transportation to and from ISS of five ESA external payloads which will be attached on the outside of the Columbus laboratory; this exchange of hardware against services is documented in a dedicated NASA/ESA bilateral agreement;

f) European Robotic Arm (ERA): this robotic servicing system will be used for the assembly and servicing of the Russian segment of the Space Station; ERA will permit to work with the new Russian airlock, being able to transfer small payloads directly from inside to outside the ISS and vice versa, thus facilitating the tasks of astronauts; also, ERA permits the transport of astronauts like a cherry picker and in this way further optimises the work of astronauts during EVA; the arm consists of 2 end-effectors, 2 wrists, 2 limbs and 1 elbow joint, together with electronics and cameras; both ends act either as "hand" for the robot, or as the base from which it can operate; ERA has a total length of 11 meters, a reach of almost 10 meters, a position accuracy of 5 mm and a launch mass of 630 kg whilst it can handle objects up to 8,000 kg. The launch date of ERA, which has been fully completed, is scheduled for end-2011 together with the new Russian Multipurpose Laboratory Module ("Nauka"), whilst an in-flight spare of the ERA elbow joint has already been launched on Space Shuttle mission STS-132 of May 2010, mounted on the Russian Mini-Research Module 1 ("Rassvet"). ERA has been built by ESA for Roscosmos on the basis of a dedicated bilateral agreement, in compensation for which Roscosmos will provide for the launch and operations of ERA in orbit whilst sharing with ESA the operational experience and feedback;

g) Microgravity Science Glovebox (MSG): the MSG enables astronauts on board ISS to perform a wide variety of materials, combustion, fluids and biotechnology experiments in a fully sealed and controlled environment whilst sharing the microgravity environment; it can also accommodate minor repairs and servicing of hardware requiring a controlled environment; MSG was launched in June 2002 by Space Shuttle mission STS-111, initially accommodated in the US Destiny laboratory and moved later to the Columbus laboratory; MSG has been built by ESA for NASA in the context of the so-called NASA/ESA Early Utilisation MOU, on the basis of which ESA acquired early utilisation opportunities on ISS prior to launch of Columbus, in combination with two ESA astronaut flights;

h) Minus 80 degrees laboratory freezer for ISS (MELFI): this facility provides up to 300 litres refrigerated volume for storage and fast freezing of life science and biological samples and covers various combinations of dewar temperatures (+4, -26 and -80 degrees Celsius); the first MELFI flight model of a series of three built, was launched by NASA in July 2006 on the STS-121 mission, whilst the third and final unit was launched on the STS-131 mission in April 2010; two out of the three MELFI units were built by ESA for NASA in the context of the same Early Utilisation MOU, as referred to above; one MELFI unit was built by ESA for the Japan Space Agency (JAXA) which provided ESA in return with twelve International Standard Payload Racks (ISPR), developed by Japan industry; the ISPRs serve to accommodate both development and flight models of the ESA Microgravity Facilities for Columbus, according to a standard interface concept for accommodation in any of the ISS laboratories (Destiny, Kibo, Columbus); this hardware exchange was based on a dedicated bilateral agreement between ESA and JAXA, concluded in November 1997;

i) Hexapod: this is a high accuracy pointing system (+/- 0.025 degree pointing accuracy, 0.0025 degree pointing stability and angular pointing rate of 1.2 deg/sec) developed to support ISS external (observation) payloads; Hexapod development was completed in November 2005 and the flight unit is being kept in storage pending the identification of a suitable NASA payload; it was built by ESA for NASA in the context of the Early Utilisation MOU, referred to earlier; and

j) Columbus Ground Software Mission Database Application (MDB) for NASA's Mission Built Facility: the MDB is a ground software tool which provides a central repository for all ISS software and data products as well as the tools to perform configuration management, consistency testing and to maintain security of these products. The products which can be stored and managed by the MDB software include the ISS flight element configuration definition, the flight software, flight procedures, displays, telemetry and command definition. ESA delivered the MDB to NASA in the period 1994 - 1997, in the context of the Early Utilisation MOU.

The above listing covered the development of hardware and software by ESA for other ISS partners; however, some other important trades between ESA and its ISS Partners are worth mentioning here as well:

- the provision by ESA to NASA of the full logistics and propulsive capacity of 5 ATV missions to ISS for offsetting (i) the ESA obligations towards the ISS partnership for its share of the running costs of ISS, the so-called ISS Common System Operations Costs (CSOC) and (ii) ESA's own transportation requirements to and from ISS for maintenance and utilisation cargo on any of the ISS logistics vehicles, in support of Columbus operations and utilisation; a program level agreement in principle was concluded between ESA and NASA in 2007, which remains to be formalised through an ESA/NASA Implementing Arrangement;
- the provision by ESA to NASA of a Super Guppy 377SGT-F transport aircraft: the aircraft and its three sister ships were built in the 1970s for Europe's Airbus Industries to ferry outsized structures for Airbus jetliners to

the final assembly plant in Toulouse, France. Its unique payload capability was identified by NASA as a key factor to reduce transport time of large structures for the International Space Station to the launch site. ESA arranged for the procurement of a Super Guppy aircraft from Airbus Industries and its transfer to NASA ownership, in exchange for ESA payload upmass on two Space Shuttle missions, on the basis of an ESA/NASA agreement concluded in 1997;
- the provision by the Canadian Space Agency (CSA) of a Microgravity Vibration Isolation System (MVIS) for ESA's Fluid Science Laboratory (FSL): MVIS is an active device which has been designed to allow fluid science experiments in ESA's FSL facility to be conducted in a low gravity environment without interference of vibrations produced by ISS, thus increasing the quality of science conducted with the FSL facility; in exchange for the CSA developed MVIS hardware, ESA is providing CSA with research opportunities on the FSL facility in Columbus, on the basis of an agreement concluded in 2001; and
- the common Rendez-Vous Sensor development for ESA's ATV and JAXA's HTV: early in the development phases at ESA and JAXA for the ATV and HTV logistics vehicles for ISS, it was recognised that both agencies could greatly benefit from a common development of this mission critical hardware; where ESA was already making good progress in this area, it was agreed to combine both ATV and HTV requirements into a common specification; this was successfully achieved and resulted in a combined contract by ESA and JAXA with an industrial company in Europe; this arrangement was based on an exchange of letters at project management level and further developed into a mutually beneficial practice of ESA and JAXA participation in both ATV and HTV project reviews.

V. "TRADING SPACE" ON ISS: BENEFITS AND LESSONS LEARNED FOR EUROPE

All of the barter (type) arrangements, as described in Chapter IV, had important benefits for Europe which can be summarised as follows:

- no transfer of funds to non-member States;
- increase in work for European industry;
- reduction of technical and financial risks for the ISS partnership;
- contribution to standardisation and commonality throughout the ISS programme; and
- strengthening of the ISS cooperation and partnership.

The scope of these arrangements is best illustrated by the fact that today more than 30% of the ISS pressurized volume has been developed in Europe (Columbus, Node 2, Node 3, Cupola and PMM).

Whilst the benefits largely outweighed any negative experiences, some of the latter are worth mentioning here:

- ISS programme delays, reduced ambitions, respectively budget cuts, particularly on the side of NASA, resulted in cancellation of interesting developments which Europe had initiated in the context of its barter obligations (e.g. X-38, Crew Return Vehicle (CRV), Cryogenic Freezer, Refrigerator/Freezer Racks (RFR));
- changes in technical requirements and/or scope of the ESA hardware to be delivered distorted the delicate barter balance, often having been achieved only through long and detailed negotiations;
- negotiations for restoring the barter balance of affected agreements, were generally very difficult and time consuming for all parties, including the related formal approval processes; and
- ISS programme delays frequently resulted in important time gaps between hardware delivery undertakings (by ESA) and the expected undertakings by the agreement partner(s); in some cases this almost defeated the original intentions (e.g. the NASA/ESA Early Utilisation MOU eventually provided NASA utilisation resources on ISS to ESA after, rather than well before, Columbus was launched).

It should also be mentioned here that through the wide-spread use of barter arrangements by ESA in the ISS programme, significant experience has been built up in the development and negotiation of such, often very complicated, agreements from a programmatic, technical and legal point of view; it represents as such a very valuable starting point for the conception of similar arrangements which will be required in the context of future human space exploration cooperation which is expected to involve an even broader, worldwide partnership than is presently the case for ISS.

VI. CONCLUSIONS

What appears at first sight as two widely different undertakings, namely the creation by the United East Indies Company (VOC) of a Dutch Trading Post on the coast of Japan in the 17th century and the construction by a worldwide partnership in the 21st century of a civil international space station ISS in outer space, revealed some remarkably identical features: these relate not only to the "outpost" nature of both endeavours, but also to the technological, scientific and cultural "transfer function" involved; whilst "trade" obviously has been the primary objective of the Dutch Trading Post in Japan at the time, it has been shown that ISS also developed into an unexpected outpost for "trading space". The ISS partners, and in particular Europe, have made extensive use of the opportunities offered in this respect by the ISS programme, and generally derived good benefits from it. The experience from this cooperation, together with the lessons learned, constitutes an excellent basis for future challenging cooperation projects in the field of human space exploration.