Text with slide 1, 2 and 3

(page down to slide 2) This academic session could have been called “Bits and Pieces **of** Aeronomy”

(click) Our colleagues have presented numerous topics, studies , projects which are the parts that together form the contribution of our institute to the science branch that is called Aeronomy

(page down to slide 3) This presentation is called “Bits and Pieces **for** Aeronomy”.

While over the past 50 years our scientists gathered bits and pieces to solve the aeronomical puzzle, a team of engineers and IT specialists went along all the way, from the very first day the institute was founded in 1964 till today, supporting the scientists, implementing their ideas, offering them platforms and infrastructure to do their measurements and calculations, transforming their requirements in real instrumentation.

If **we** say bits, we mean bits like in transmitting megabits of data to ground (click) or bytes like in Terrabytes of storage capacity on disk or in the cloud (click)

If **we** say pieces, we mean mechanical parts (click), electrical components (click), computers (click) or servers (click)

Text with slide 4, 5 and 6

(page down to slide 4) Vijay Kumar, an Indian roboticist and professor at the School of Engineering and Applied Sciences of the University of Pennsylvania, made, probably on a blue Monday, the following statement (click).

“Without engineers and IT-guys, science is just philosophy”

We added the wink smiley ourselves, because quotes are just … quotes. The truth for some, a lie for others and often something in between. But since we are engineers and IT-guys, we admit that we do fancy the expression.

(page down to slide 5)

(click) Don’t you agree that life would be less exciting without technology.

(click) That life would be less efficient without technology.

(click) That life would be less practical without technology.

(click) That life would be much more tiring without technology.

And what is science other than life itself.

(page down to slide 6) (click) Professor Kumar was born only two years before the Belgian Institute for Space Aeronomy was created. We assume that the founding fathers of our institute were not acquainted with his famous quote. Nevertheless they were convinced that this young science, they called aeronomy, could not grow without reaching the hand to technology.

But as much as science needs technology, technology also needs science, for it is the playground where inventions are made and the future is shaped. Science, engineering and information technology at our institute go hand in hand.

Text with slide 7 and 8

We are happy to say that this fundamental idea has not changed over the past half century. Engineering and IT played and play a prominent role in the history and strategy of our institute.

For over four decades Engineering and IT were part of one department, (page down to slide 7) the department of Applied Aeronomy. All the credits for the evolution, the expansion and the impact of Engineering and IT in our institute go to three engineers who lead this department from an era (click) where electronic tubes were on the verge of disappearance, (click) transistors only just emerged, (click) computers where bigger than a refrigerator and had merely the capacity of a modern hand calculator, into the twenty first century (click).

(click) Dirk Frimout (until he left the institute in 1978 to become Belgium's first astronaut), (click) Dennis Nevejans (until he retired in 2007) and (click) Carlos Lippens (until he retired in 2008) never ceased to introduce state of the art engineering and information technologies in the institute and put them at the service of the scientists.

Only some ten years ago it was decided to have (page down to slide 8) separate services for engineering and IT, mostly due to the fact that the IT needs of the scientists boomed spectacularly.

Today Engineering and IT support projects that can be ground based (click), air or space borne (click) and are active in a wide range of domains such as mechanical design (click), software development (click), ground support equipment (click), electronics design (click), on board firmware (click), mechanical manufacturing (click), prototyping and testing of equipment (click), operations (click), project management (click), web design (click), high performance computing (click), data storage (click), networking (click), processing-administration (click), infrastructure management (click), interconnectivity (click), personal computing (click), IT consultancy (click)

Text with slide 10, 11 and 12

But how can we demonstrate better what are the tasks and domains of competence of Engineering and IT, than by showing you the past and ongoing achievements of our teams.

Allow us to take you on a very short journey through 50 years of designing, manufacturing, assembling, testing and using of scientific instrumentation and information systems. We are sure we will encounter on the way some of the projects mentioned in the earlier talks of our colleagues (page down to slide 10).

By the time ESRO, the European Space Research Organisation, the precursor of ESA, puts its first Skylark and Centaure sounding rockets in the atmosphere and its first satellites in space, also the institute becomes active in developing experiments (click).

In the early years electronics for scientific instrumentation consisted of discrete components: transistors, hybrid operational amplifiers, resistors, condensers. Programming of equipment was based on mechanically driven timers, data was recorded by means of penrecorders and paper. (click) The engineering team at BIRA built payloads for rockets, measuring amongst others the UV radiation, (click) and for the very first balloons at the end of the sixties, carrying optical and mass spectrometers into the stratosphere up to between 20 and 50 kilometers and ranging in weight between 10 and 300 kilograms.

In those years the complex mathematical calculations and data processing, needed by the scientists for their physical and chemical modelling, were done by calculators. These were no machines, but physical persons doing the calculations with pencil, paper and slide ruler.(page down to slide 11)

The concept of high-end computing was introduced quite rapidly. (click) Computers such as the IBM1800 (which was only programmable by electronics experts) (click), the HP2100 minicomputer (with a huge 32kbyte memory) (click), the HP1000 minicomputer (later used as ground support equipment for 2 shuttle missions) (click) and a UNIVAC 1100 mainframe all did duty at our institute

(page down to slide 12) (click) Initially there was no IT personnel yet. The BISA-engineers were the pioneers of these emerging computing activities. (click) Our "flesh and blood" calculators started using the "electronic calculators" and the first computers, programming them in Basic and Fortran.

<u>Text with slide 13, 14 and 15</u>

(page down to slide 13) With the signing of the ESA convention and hence the official start of the European Space Agency in 1975, Europe gave form to its dream to follow Russia and the United States in the conquest of space and stepped into a decade of wonder years.

In our institute engineering and IT marched on, following closely the fast evolutions in micro-electronics and computing. Bigger mainframes replaced their precursors and offered more calculating power to the scientists. But also data storage changed dramatically. Data and computer programs were initially stored on punch cards (click), later on paper tapes (click), or on tape reels (click) and finally on hard drives (click) as big as a refrigerator with a mind boggling storage capacity of … 1 Mbyte.

(click) Slowly also the personal computer started taking over part of the work of the centralized mainframes.

(page down to slide 14) (click) Balloon campaigns remained one of the key activities in Engineering (click), sometime launching up to 4 instruments per year (click). Stabilized platforms were introduced with the possibility to accurately point the line of sight of the instrument.

Little by little integrated circuits and logic devices such as flipflops (click) and logic gates (click) found applications as instrumentation grew more complex and digital remote communication became a necessity. Heavy led batteries were replaced by much smaller and reliable Ni-Cd batteries and later by lithium batteries (click).

Although the capabilities of the first microprocessors (click) were negligible compared to what processors can perform today, the new techniques were introduced and applied from the very beginning

(page down to slide 15) (click) One of the biggest achievements of Engineering in this period was the participation in three instruments, that were placed on board NASA's SPACELAB-1 module in 1983. The institute had important contributions in the ALAE instrument and the GRILLE spectrometer. (click) The third instrument was SOLSPEC, which was built in collaboration with the Service d'Aéronomie in Paris (click), now LATMOS, an institute that has always been closely linked to ours. The SOLSPEC instrument would later be rebuilt and reflown several times, on EURECA in 1992, and on three ATLAS missions in 1992, 1993 and 1994. (click) But also the GRILLE spectrometer would fly again. On Atlas 1, in 1992, together with Dirk Frimout, and on the Russian space station MIR in 1994.

Text with slide 16 and 17

(page down to slide 16) For Belgium, but also for our institute, the next decade is undoubtedly marked by the fact that one of its pioneers and engineers, Dirk Frimout, became the first Belgian astronaut in history, when he flew aboard mission STS-45 of Space Shuttle Atlantis in March 1992.

Frimout had left the institute but research and engineering work didn't stop. On the contrary. Aeronomy boomed when international consciousness regarding the alarming change of our climate, awoke .

(click) Balloon flights went on, lifting now mass spectrometers of over 500 kg into the stratosphere, built in house (click) by engineers and technicians from the mechanical workshop and the electronics lab.

(page down to slide 17) (click)The most eye-catching accomplishment was without any doubt the fact that the institute placed two of its instruments on board EURECA(click), ESA's European Retrievable Carrier, that was launched and deployed in 1992 (click) and retrieved in 1993.

Besides SOLSPEC also ORA (click), which stands for Occultation Radiometer, was on board. The institute played an important role in the scientific conception and consequent data analysis, but it was also strongly involved in the building and testing of this instrument.

And from the IT side? Business as usual, meaning: increasing year after year in capabilities, computing power and storage capacity, in order to deal with the experimental data that is now electronically captured. This goes hand in hand with a fundamental shift in research methodology, introducing automated data processing and numerical simulations. Inside the engineering department, IT becomes more and more a self-contained service, delivering dedicated support to the users of the developing IT infrastructure.

Text with slide 18, 19 and 20

(page down to slide 18) The period 1995-2005 is the decade that underlines ESA's resolve to conquer the solar system with the launches of Mars Express in 2003, Rosetta in 2004 and Venus Express in 2005.

Isn't it amazing that a small institute as ours, is prominently present in all three of these missions, with important hardware contributions, becoming like that an important player also in planetary and cometary aeronomy.

(click) However, this time frame started really catastrophically with the failure of the Russian Mars-mission MARS-96, that crashed few minutes after its launch in 1996 (click). With MAREMF and SPICAM-S, the institute had two instruments on board (click). SPICAM-S was an optic spectrometer, designed in house, and its loss was a real pity. But it would leave a legacy. The heritage of SPICAM-S would be used to build, together with the French Service d'Aéronomie, the SPICAM-Light instrument on Mars Express (click), and the SPICAV-SOIR instrument on Venus-Express (click), two highly successful missions and two highly successful instruments that today are still active.

Contrary to ground based instrumentation, building instruments for space is something a small engineering team can not do on its own. Intensive collaboration was set up with the Belgian industry, such as Verhaert for SPICAM-S (click) and OIP Sensor Systems for SOIR (click).

Typical of this period is the tendency to embark more and more intelligence on board these scientific instruments (click), making them quite versatile measuring benches in space. This was made possible by the further evolution in electronics, especially with the development of performant space qualified microcontrollers, microprocessors and Field Programmable Gate Arrays.

(page down to slide 19) Very recently Rosetta became head line news again, ten years after its launch. When last August it finally arrived at comet C-G the first amazing measurements were performed from the orbiter. Two weeks ago Philae landed on the comet. (click) One of the instruments on board Rosetta is DFMS. It is a double focusing mass spectrometer that is part of the Rosina suite. (click) The institute played a major role in building the instrument. It developed the detector of DFMS, a linear electron detector array, together with IMEC (click), and the read out electronics of the detector (wait enough) together with OIP.

(page down to slide 20) In the test lab and during flight, more and more, workstations (click) are used as ground support equipment for instruments. The development of ground support software has gone hand in hand with instrument development in our team. But also in the central computer rooms of the Space Pole, investments go on with the installation of a new generation of supercomputers such as the Cray Jedi (click) and the SGI Origin (click) as well as the first centralized mass-storage systems, all at the service of the new demanding numerical modeling algorithms. These large scale systems and infrastructures are all procured and operated jointly with our colleagues of the RMI and the Royal Observatory, under the flag Amabel. This highly successful collaboration is approaching it's 30th birthda

The advent of the internet (click) accelerates the pace of IT development and for the first time the IT infrastructure becomes critical to the day-to-day functioning of the institute. (click) By the year 2000 nobody can live without e-mail, google & co. and the by now VERY personal PC.

Text with slide 21, 22, 23 and 24

(page down to slide 21) As landmark in the last decade we have of course chosen the celebration of the 50th anniversary of our institute and we have called this period “the adult years”. Half a century of science in aeronomy and half a century of accompanying engineering and IT work have made us a full grown player in the international scientific community.

(click) The engineering team is working with modern CAD tools for mechanical designing (click) and with the latest electronic design software tools. Our engineers are and will be more than ever involved in ground based instrumentation and space applications. Our hardware can be located nearby, (click) in a field (click), on a rooftop (click), in a tree (click). It can be installed at the most exotic locations (click) at the other side of the world. Contributing to ground instruments with mechanical and electrical hardware, supporting them with operation and automatization, is an non negligible part of our day-to-day work.

(page down to slide 22) Our hardware can also be embarked on board of minisatellites, like the Energetic Particle Telescope EPT (click) on board PROBA V, launched in 2013, in which the institute contributed with mechanical hardware, or ALTIUS (click), a spectral imager under development, to be launched also on a PROBA platform. It can be on a picosatellite like PICASSO (click) carrying miniaturized scientific equipment.

(page down to slide 23) But it can also be on one of ESA’s large size mission like the Trace Gas Orbiter (click), the first segment of the ExoMars program, to be launched in January 2016. With the NOMAD instrument (click) the institute again has an important technical contribution: (click) electronics boards, on board software, ground support equipment, mechanical parts and a high tech flipping mirror mechanism, one of the specialties of our team.

(page down to slide 24) Today our institute stores more than 300 Terrabytes of scientific data. That is roughly equivalent to 60.000 Compact Disks. (click) In the future novel solutions will have to be found to continue storing and processing the increasing amount of data. A real challenge.

(click) The actual computing power at the institute has increased by a factor of 1trillion with respect to the early days and we are on the verge of increasing this by another order of magnitude. This is completely in line with Moore’s law and futurist Kurzweil’s thesis which states the following: (click) the accelerating pace of change (click) and the exponential growth in computing power (click) will lead to a singularity. Moore predicts that by next year (click) single computers will exist that surpass the brainpower of a mouse, (click) by 2023 that of a human and (click) in 2045 of all mankind.

In anticipation of this glorious day, when we can all retire and leave research and development to the computers and robots, (click) the now independent IT department tries to use simple grey matter (click) to automate routine tasks –be they administrative or for research-,   to manage the increasingly complex IT infrastructure, the related services and(click) the ever more imaginative ways in which our scientists use the new technologies.

Text with slide 25

(page down to slide 25)

Speaking about technology. We would like to mention also that, besides the Engineering and IT service, the institute houses another important pole of technological competence. The Belgian User Support and Operations Centre offers to scientists services ranging from engineering support, over knowledge and project management, to mission operations. They played for example a primary role in the operations of SOLSPEC on the SOLAR platform or of EPT on PROBA-V, and will contribute to the NOMAD operations on ExoMars.

Text with slide 26

(page down to slide 25) We would like to take advantage of this occasion to say a word about yet another service in our institute. The service has not been in the spotlights today although, without it, this event, and all other events that were organized at the occasion of our 50th anniversary, would not have been possible.

Managing the website of the institute (click), editing the yearly reports (click), interfacing with the press (click), organizing appearances in the media (click), and many more. The communication service at the institute brings, through educational programs (click) and public outreach at numerous events (click), our scientific and technical achievements under the attention of society.

Text with slide 27

(page down to slide 26) Although the fields of application of engineering, IT and communication may be diverse, our three services and the B.USOC have a common ground. We try to contribute, each in our own way to better science, or a world were science can be performed in the best of conditions.

As the title on this last slide says, for sure, our services deliver very concrete bits and pieces **for** Aeronomy, but we proudly think that all the things we do (click) are just as well bits and pieces **of** Aeronomy