EXPReS & FABRIC at JIVE

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JOINT INSTITUTE FOR VLBI IN EUROPE

EXPReS

What is EXPReS?

- EXPReS = Express Production Real-time e-VLBI Service

- Three year project, started March 2006, funded by the European Commission (DG-INFSO), Sixth Framework Programme, Contract #026642.
- Objective: to create a distributed, large-scale astronomical instrument of continental and inter-continental dimensions.
- Means: high-speed communication networks operating in real-time and connecting some of the largest and most sensitive radio telescopes on the planet.

EXPReS' Goal

The overall objective of EXPReS is to create a **production**-level, **real-time**, "electronic" VLBI (e-VLBI) service, in which the radio telescopes are reliably **connected** to the central **supercomputer** at JIVE in the Netherlands, via a high-speed optical-fibre communication **network**...

- or -

Make e-VLBI *routine, reliable* and *realistic* for astronomers.

Why e-VLBI?

- To get more and potentially better scientific results much faster than with traditional VLBI.

- e-VLBI:
  - Dramatically shortens the delay between observations and the resulting images.
    - From months to days or hours.
  - Can offer more frequent and reliable observations with potentially more bandwidth * observation time.
    - Ensures data quality already during observations, relaxes storage requirements for raw noise data.
  - Enables a new class of fast response and reactive observations.

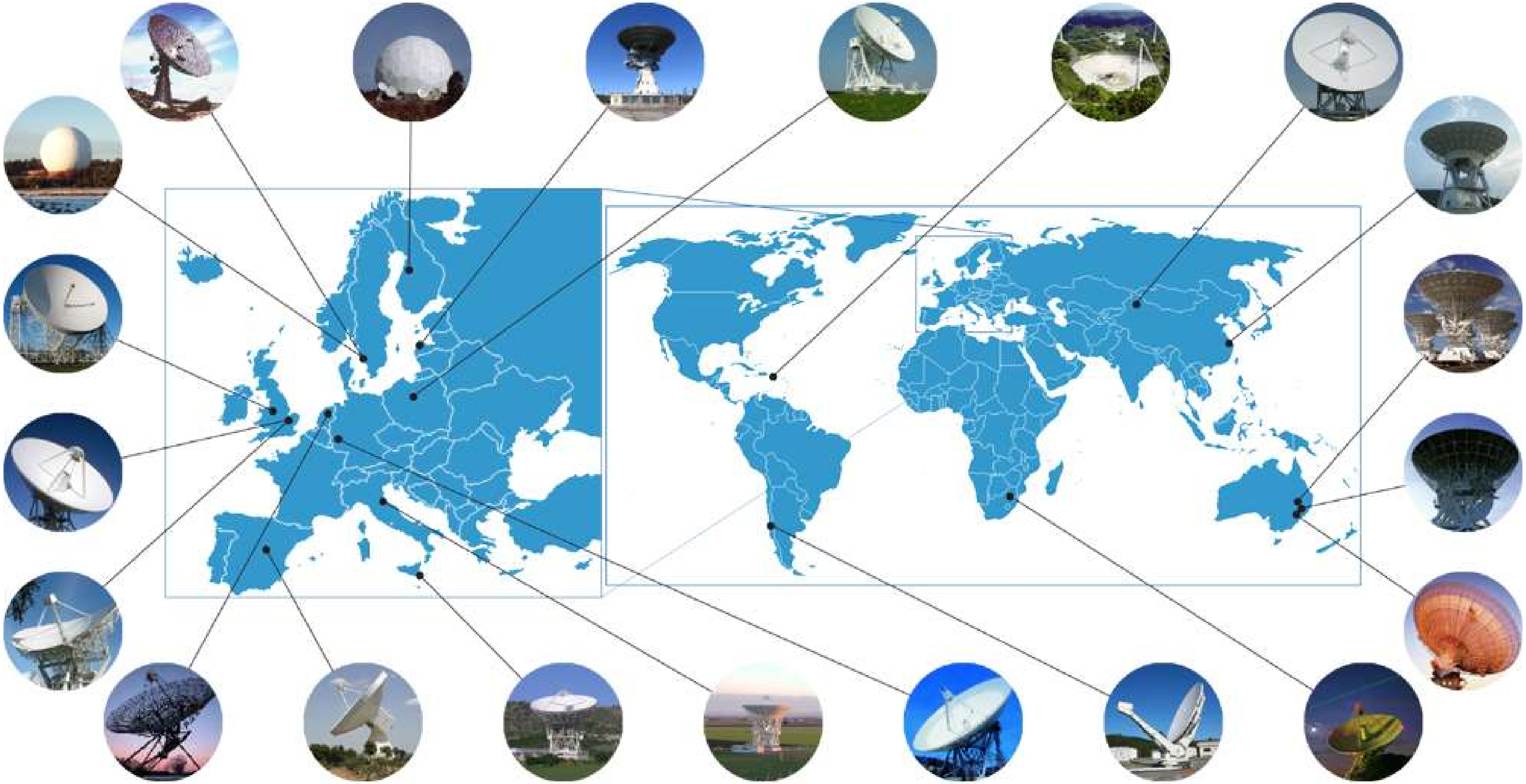
Activities

#	Description	Leader
PC	Project Coordinator	Huib Jan van Langevelde, JIVE
NA1	Management of I3	T. Charles Yun, JIVE
NA2	EVN-NREN Forum	John Chevers, DANTE
NA3	eVLBI Science Forum	John Conway, Chalmers
NA4	Public outreach	Kristine Yun, JIVE
SA1	Production Services	Arpad Szomoru, JIVE
SA2	Network provisioning	Francisco Colomer, CNIG-IGN
JRA1	FABRIC	Huib Jan van Langevelde, JIVE

EXPReS Partners

- Joint Institute for VLBI in Europe (coordinator)
- AARNET Pty Ltd., Australia
- ASTRON, the Netherlands
- Centro Nacional de Informacion Geografica, Spain
- Chalmers Tekniska Hoegskola Aktiebolag, Sweden
- Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
- Cornell University, USA
- Delivery of Advanced Network Technology to Europe Ltd. (DANTE), UK
- Instituto Nazionale di Astrofisica, Italy
- Instytut Chemii Bioorganicznej PAN, Poland
- Max Planck Gesellschaft zur Foerderung der Wissenschaften e.V., Germany
- National Research Foundation, South Africa
- Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
- SURFNet b.v., The Netherlands
- Teknillinen Korkeakoulu, Finland
- The University of Manchester, UK
- Universidad de Concepcion, Chile
- Uniwersytet Mikolaja Kopernika, Poland
- Ventspils Augstskola, Latvia

Telescopes participating in EXPReS



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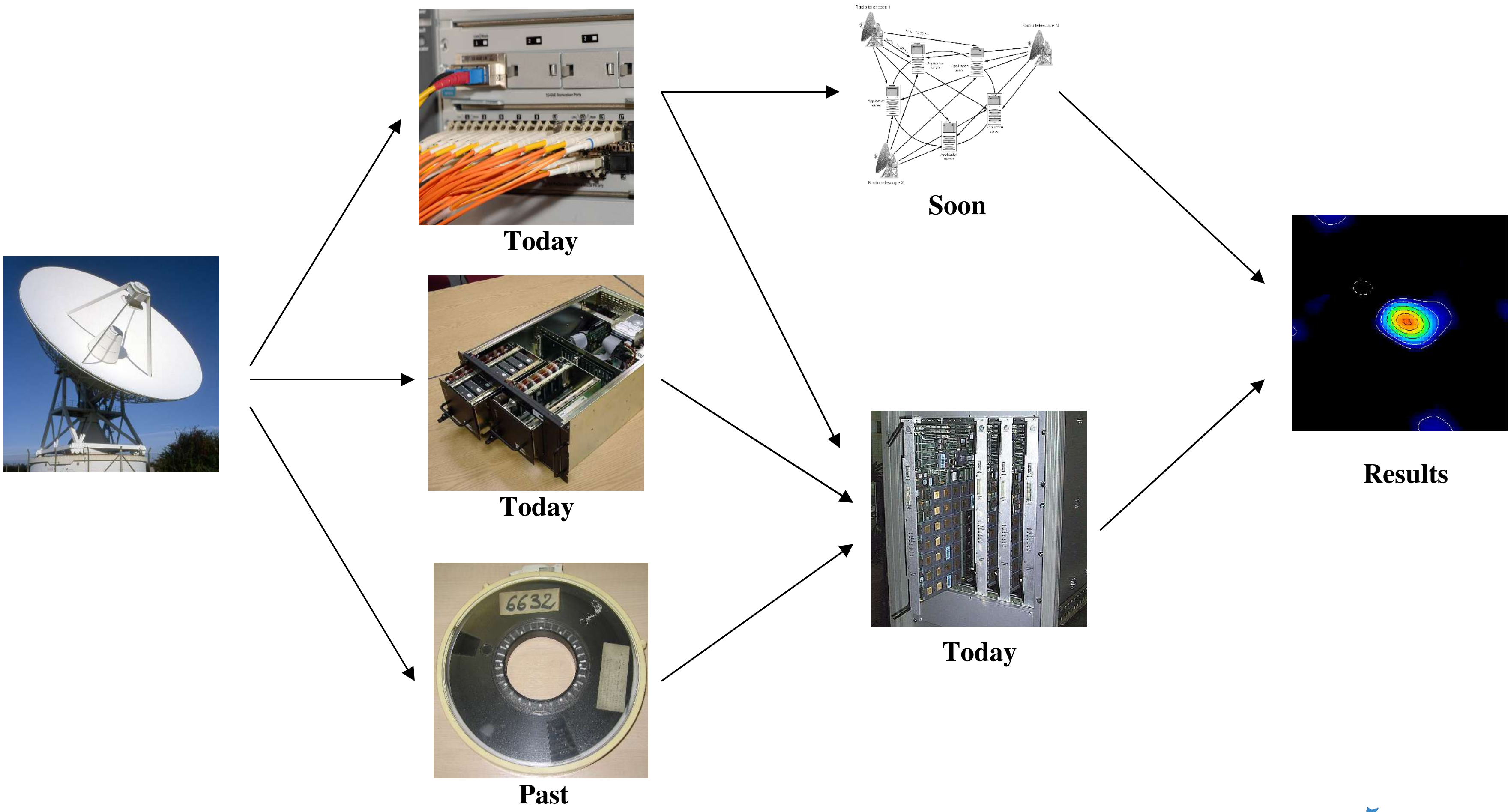
Telescope photos used with permission.

e-VLBI, VLBI, Radio Astronomy

- A radio telescope looks at an object in the sky and collects data to create an “image” of the source. The bigger the telescope, the better the image (resulion, sensitivity).
- Instead of building a single big telescope, multiple telescopes can be used to make an image. The bigger the distance between telescope the better the resolution of the resulting image.
- Signals from multiple telescopes need to be correlated. This extracts the interferometry information from the raw radio noise data.
- The sensitivity of the interferometer depends on the collecting area and data rate. Higher data rates means we can observe fainter sources.

Data Flow



Aperture Synthesis Imaging

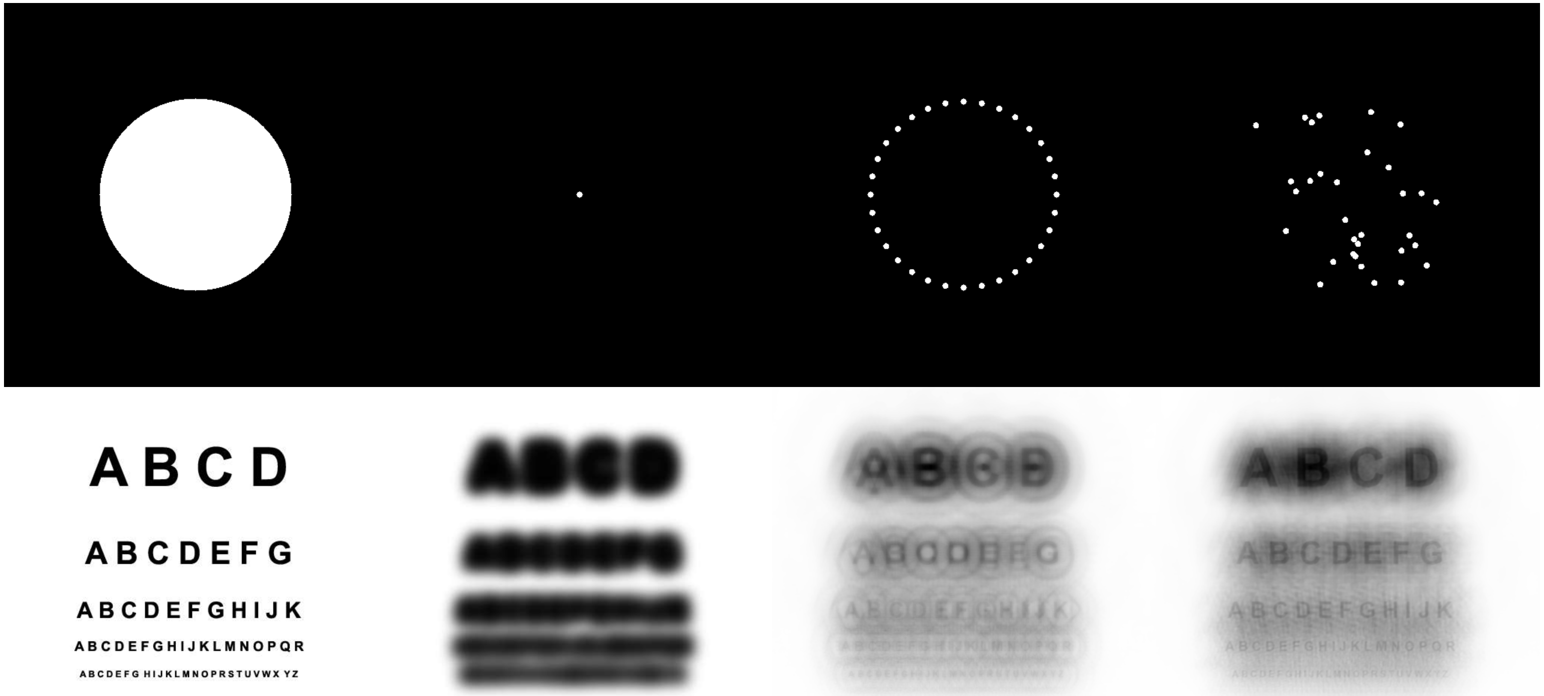
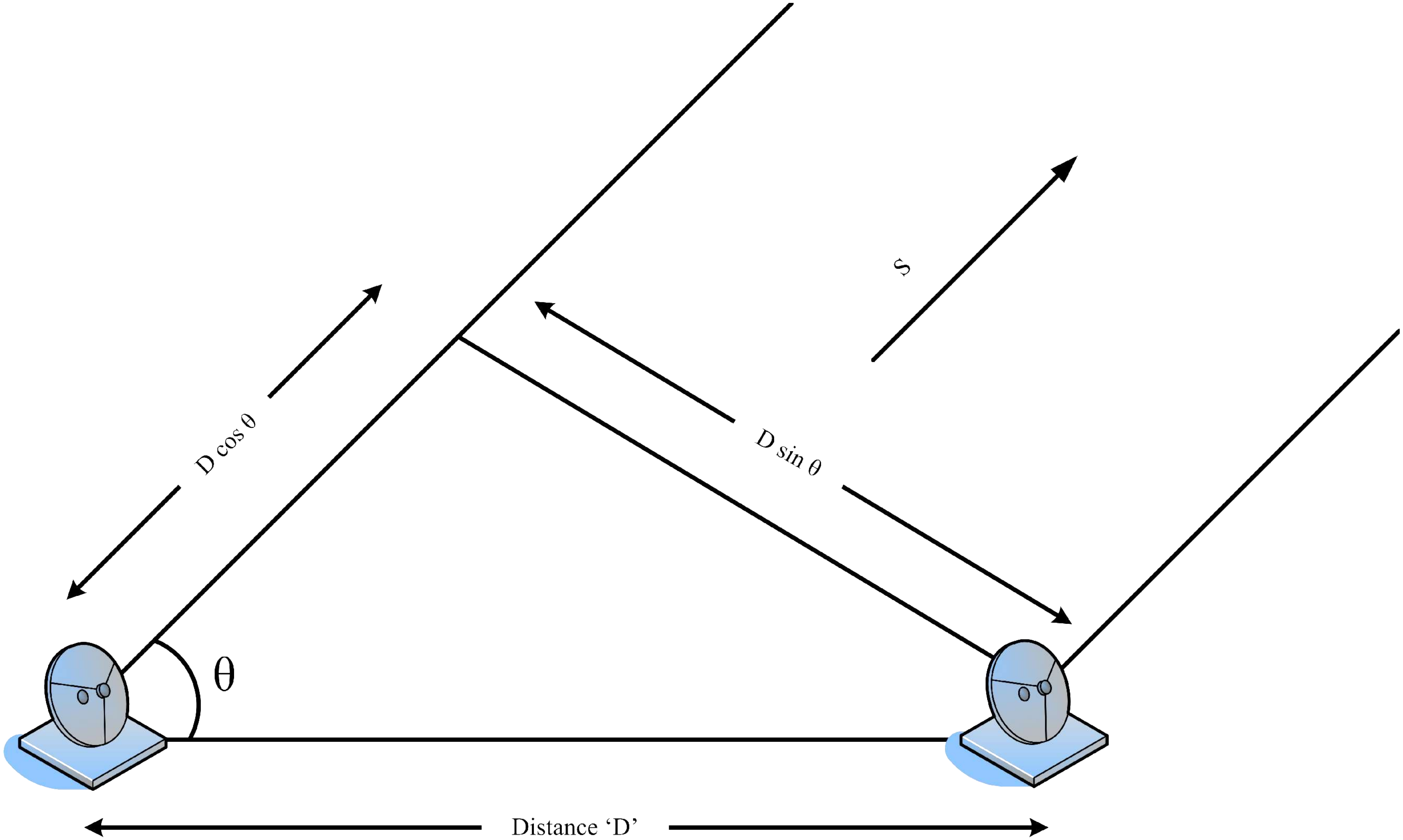


Image Credits: Avruch and Pogrebenko

- A technique that uses a number of telescopes to simulate a much larger one. A larger dish, real or simulated, improves image clarity and brightness. This requires coordination between the telescopes and a supercomputer. Consider the examples displaying aperture size, aperture distribution and image quality.

Correlation



Network and compute technologies

- To assess the suitability of advanced networking and computing technology to support the creation of a next-generation e-VLBI network in which the aggregate data flows will be many hundred of Gbps with a data processing environment possibly based on distributed Grid-based computing resources.

- Getting real VLBI fringes with experimental technologies:
  - ”Month 7” Demo
  - Grid correlator software.
- Next-generation hardware architectures and networking protocols have been identified and design is progressing.

Future Arrays of Broadband Radio-telescopes on Internet Computing

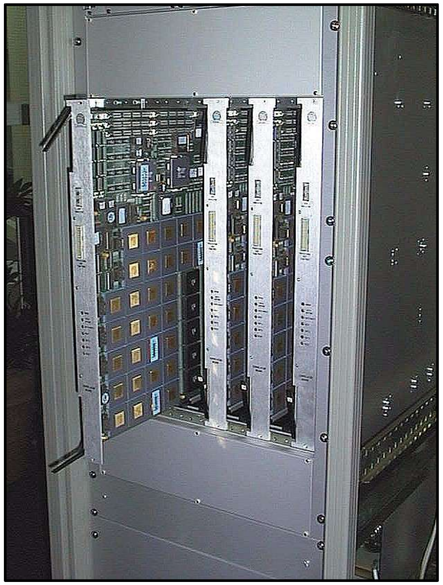
WP 1.

- Broadband
  - Data acquisition to work with 10Gbps Internet
    - Requires new filtering and sampling hardware
  - Optimize protocol
  - Calibration issues and control software interface to telescope
  - Interfaces from public domain transport to “private”
    - LOFAR
    - e-MERLIN
- Prototype and test
  - Onsala telescope on e-MERLIN

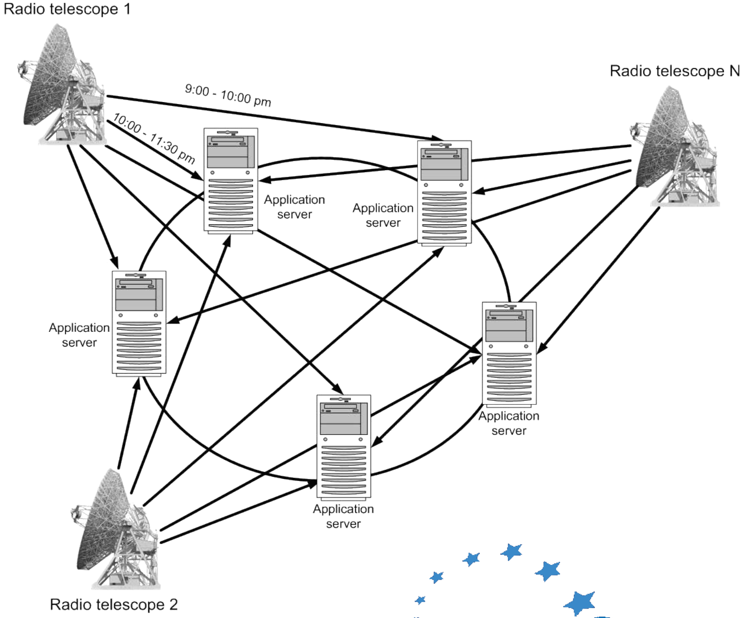
WP 2.

- Internet computing
  - Use Grid for calculating correlation function
    - Based on virtual lab projects
    - Workflow management
    - Load balancing
  - Deployable software correlator
    - based on previous Huygens machine
    - suitable for Grid nodes and parallel computing
    - Data quality control, display and merging
- 5 station demonstrator
  - with new science capabilities

Distributed Correlation



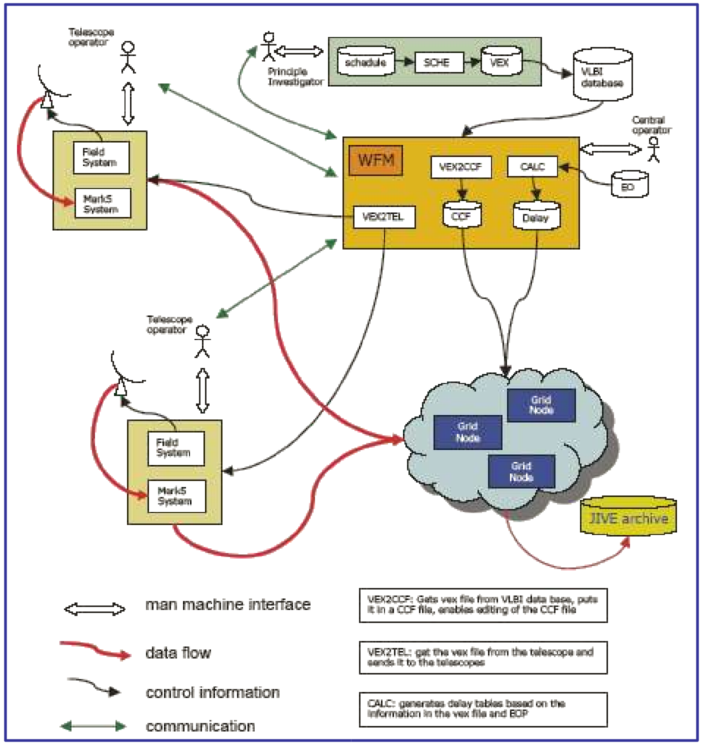
- Correlation currently in dedicated silicon
  - special purpose computer
  - with 2 bit operations
  - at 40 T-ops
  - Future needs at 20 P-ops
  - So called XF correlator
- Can be done on custom computers with 1op=1flop
- But it makes sense to use a different algorithm
  - So called FX correlator
  - Interesting science demo woud take a few cluster computers
  - Software correlation can outperform 2 bit operation
  - Make use of the geographical distribution of telescopes?



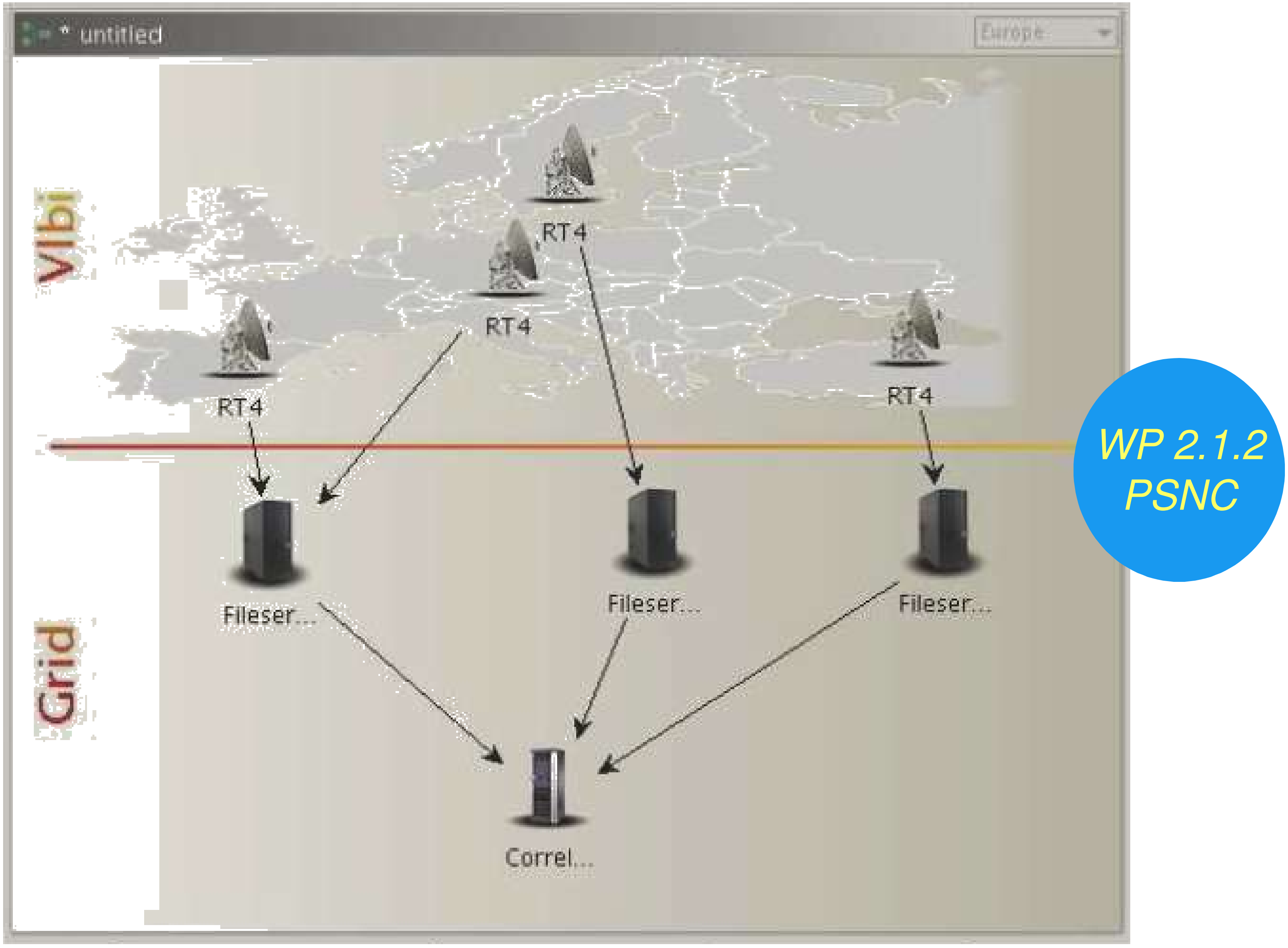
eVLBI-Grid collaboration

WP 2.1.1
PSNC

- Connect telescopes and correlator nodes
  - need to be deployed on Grid
  - based on virtual laboratory paradigms
- Challenge: resource allocation
  - Handled by special VLBI grid broker
  - Uses results from network monitoring
  - Driven by workflow manager
  - Software correlator needs to be integrated



EXPReS



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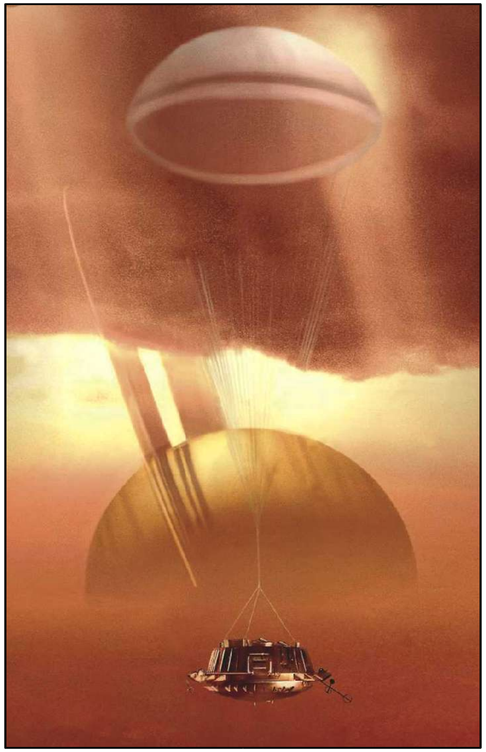
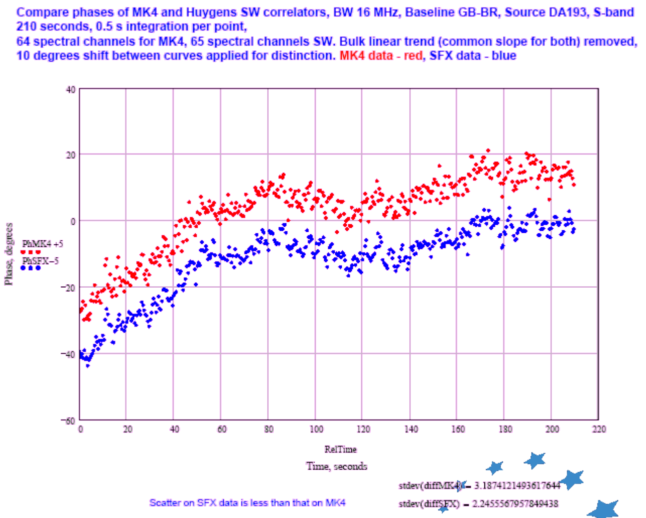
Correl...
WP 2.1.2
PSNC

Software Correlator

WP 2.2.1
JIVE

- Deployable software correlator
  - Cluster computer enabled
  - Grid enabled
- Starts with special purpose algorithm for Huygens mission
  - Extreme high spectral resolution
  - Keep for future applications
- Can have better signal to noise performance than 2-bit
  - Interesting astronomy applications





FABRIC Milestones

Number	Description	Lead	Delivery	Type
J1.12	Software correlator core	JIVE	June 2007	Software
J1.13	Software data product	JIVE	August 2007	
J1.16	Software for Workflow Management	PSNC	September 2007	Software
J1.17	Software for correlation on cluster	JIVE	February 2008	Software
J1.21	Software cluster correlation	JIVE	February 2008	Demo
J1.22	First fringes software correlator	JIVE	February 2008	Demo
J1.23	Software to collect distributed output	JIVE	September 2008	Software
J1.24	Software to create data product from distr. corr.	JIVE	October 2008	Software
J1.25	Software routing	PSNC	August 2008	Software
J1.26	Fringes with new routing	JIVE	October 2008	Demo
J1.28	Software distributed correlation	JIVE	December 2008	Software
J1.29	First fringes distributed correlator	JIVE	January 2009	Demo
J1.30	First fringes on FABRIC	JIVE	February 2009	Demo
J1.31	Final report	JIVE	March 2009	Report