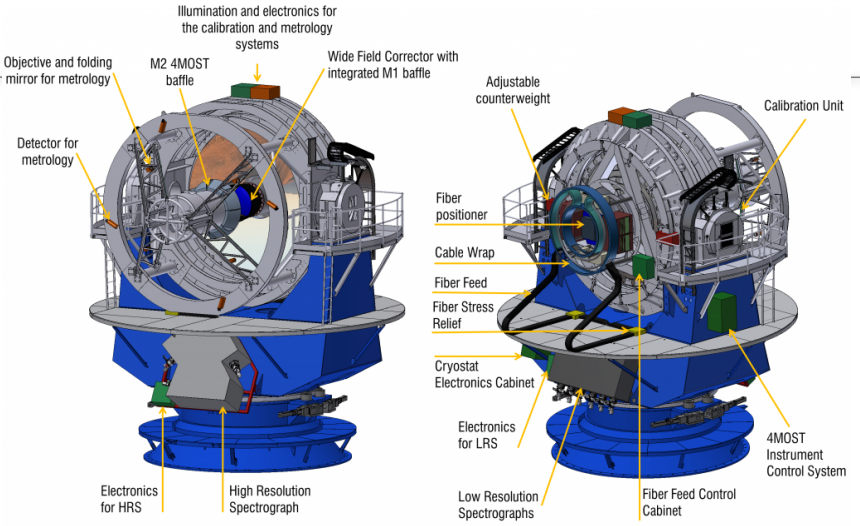
4MOST – 4m Multi-Object Spectroscopic Telescope

4MOST: Science operations for a large spectroscopic survey program with multiple science cases executed in parallel

C.J. Walcher (AIP)

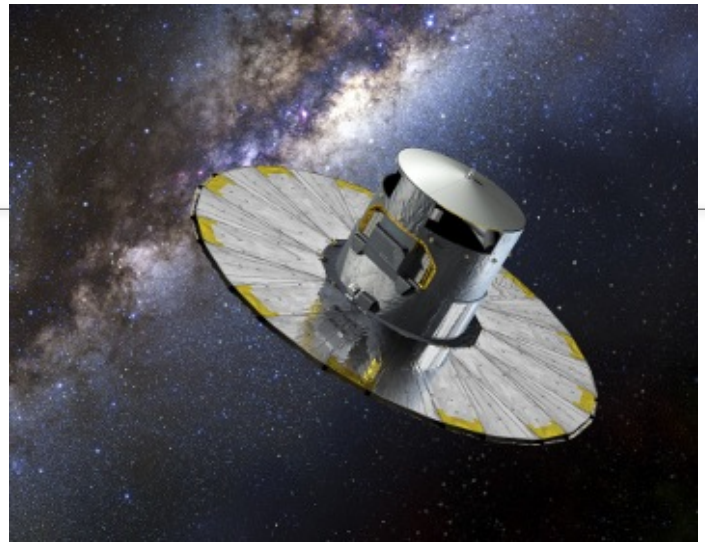
www.4MOST.eu

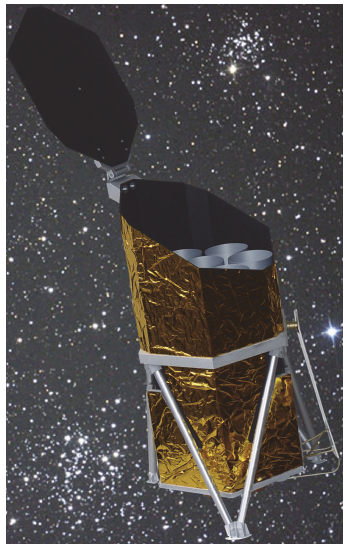
4MOST in a nutshell



- Multi-object spectrograph on VISTA telescope @ ESO
- Optical wavelength range
- Low Res (R~5000, 1600 apertures)
  High Res (R~20000, 800 apertures)
- Grid positioner, fiber based
- 75 Million 20 minutes spectra in 5 years

4MOST science

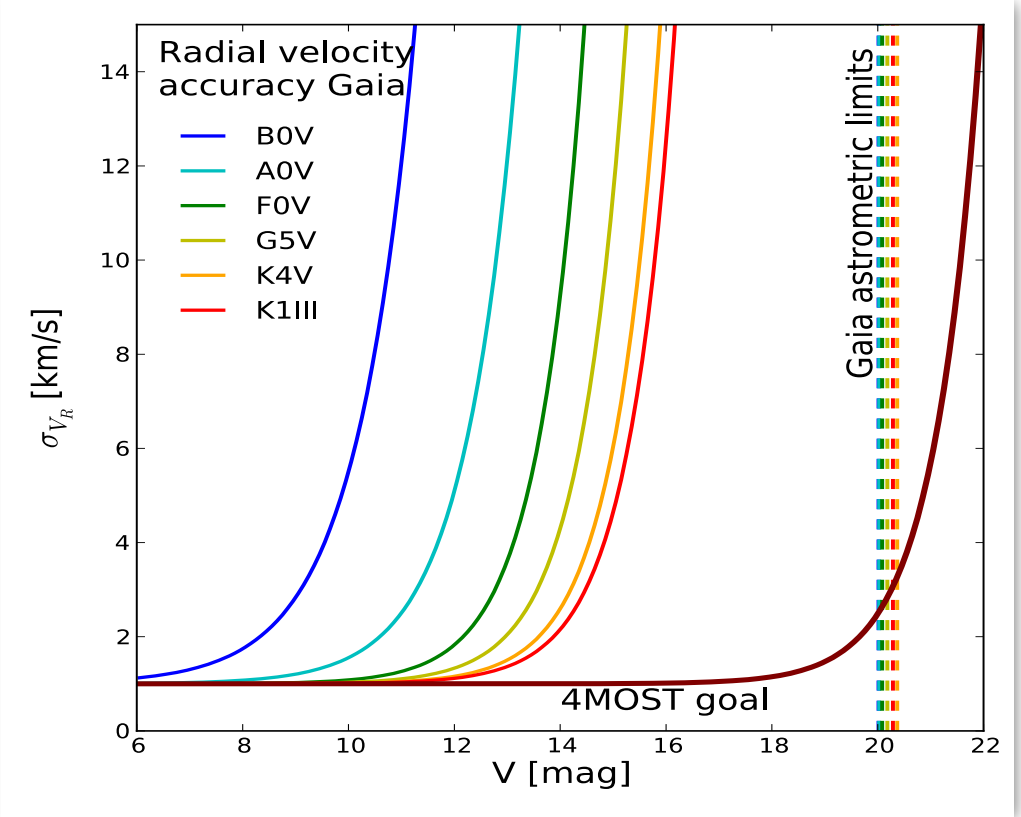




- Galactic
  - Gaia follow-up
  - Stellar velocities and abundances
- Extra-galactic
  - eRosita, Euclid, LSST, etc. follow-up
  - Redshifts, line ratios, (stellar populations)

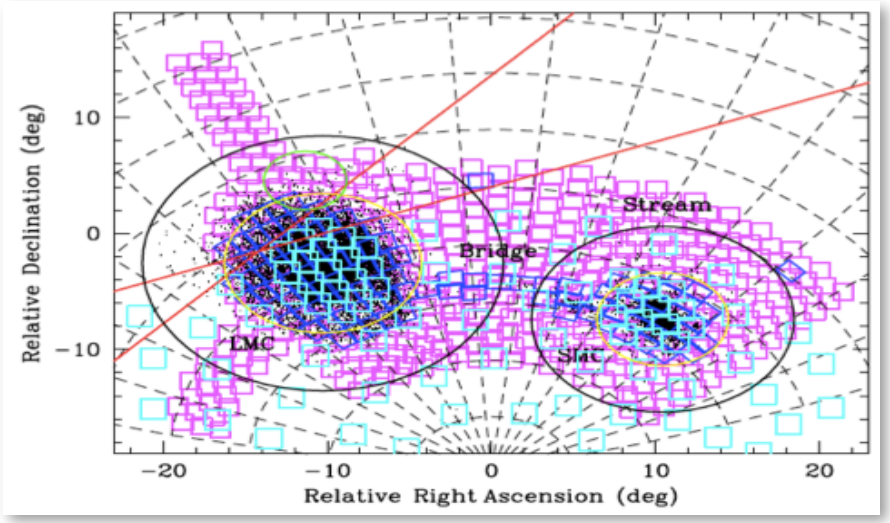
Galactic Archeology - Gaia

- Chemo-dynamics of Milky Way stars allow to determine evolutionary history and structure of our cosmic home
- Gaia measures distances and proper motions for >2 billion stars
- 4MOST will complement Gaia with radial velocities and chemical composition for faint stars
- Four consortium surveys, half the total consortium targeting rights



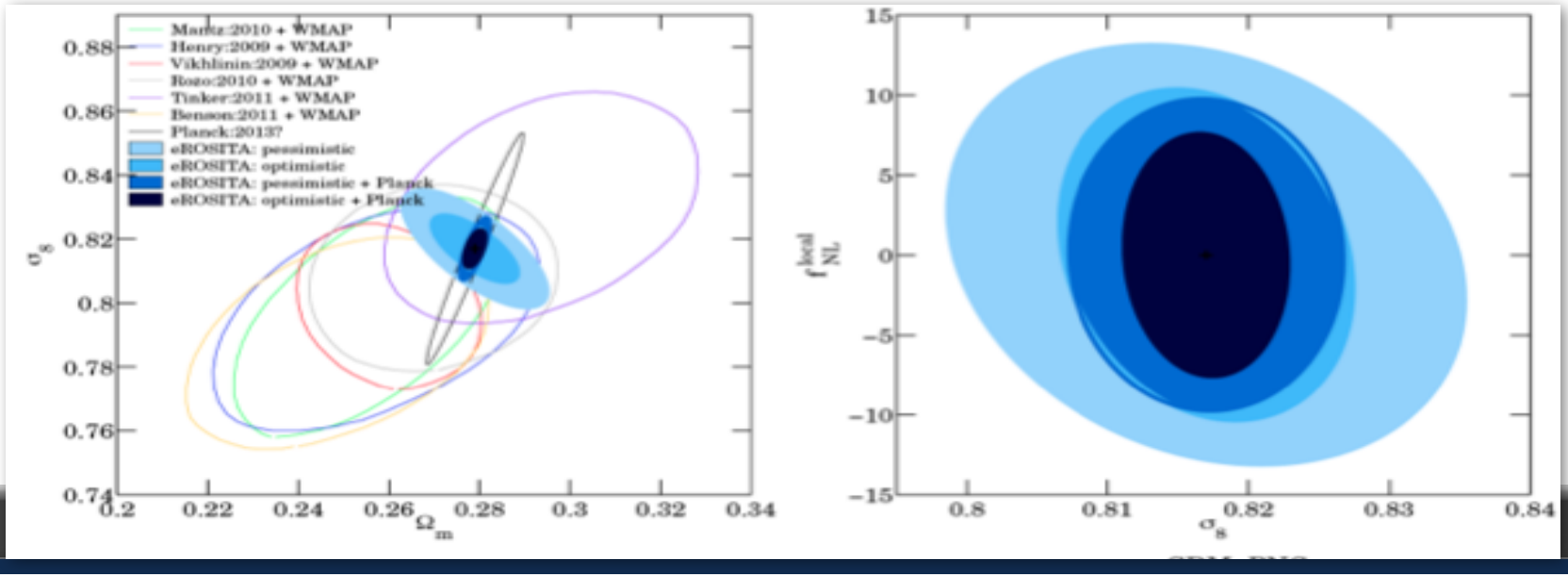
Magellanic Clouds - VISTA

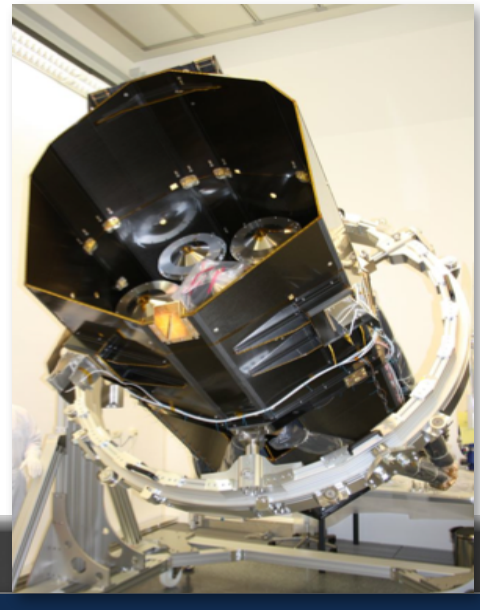
- Dynamical structure of the Magellanic Clouds and their interaction with the Milky Way
- Star formation history of the Clouds
- Dark Matter structure of the Clouds
- Properties of rare stellar populations to constrain stellar evolution models



X-Ray sky - eRosita

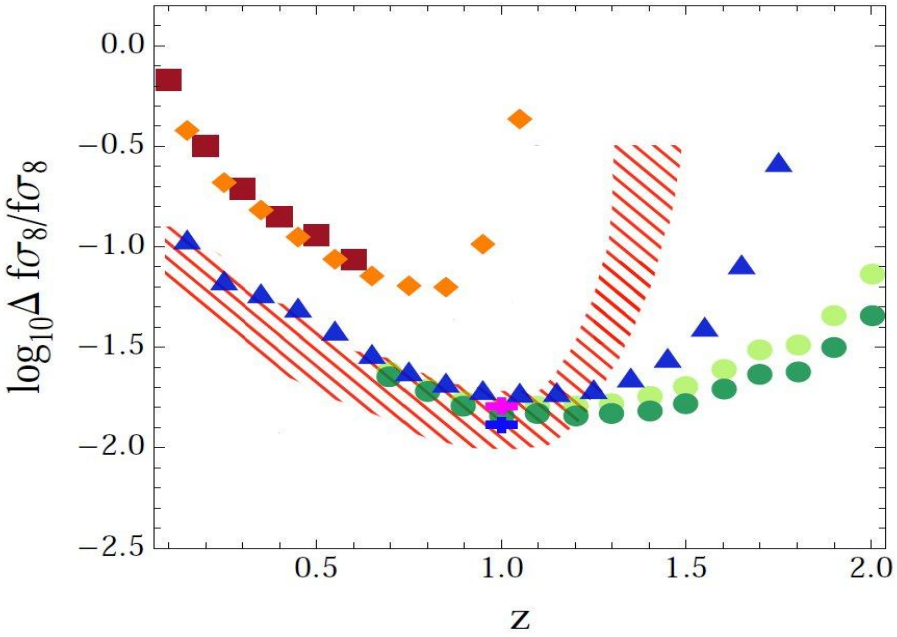
- German - Russian X-ray mission, Launch March 2018
- 8x all sky survey, 0.5 –10 keV
- *Dark Matter and Energy, growth of structure*
- Strong cosmology constraints from Galaxy Cluster evolution
- AGN evolution and Galaxy-Black Hole co-evolution
- Active galactic compact objects to constrain stellar evolutionary channels





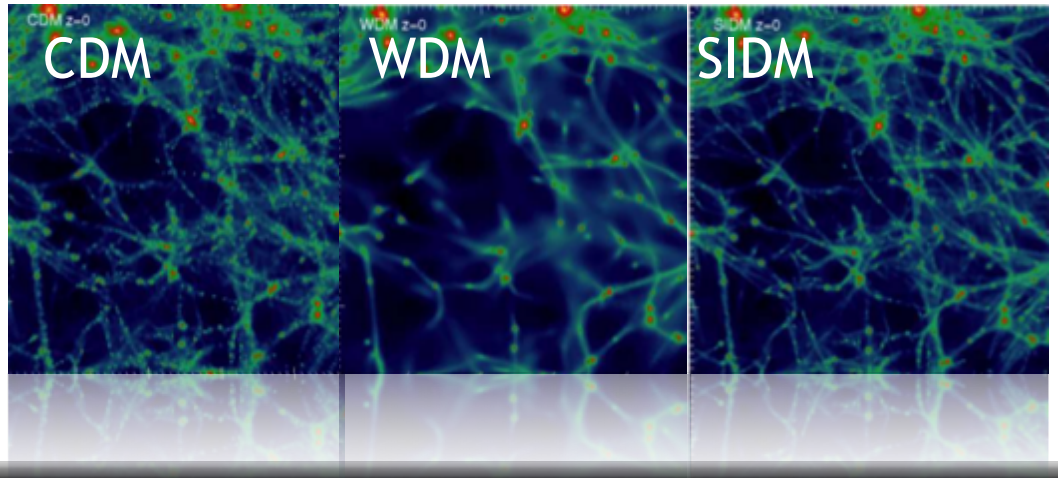
Cosmology - Euclid

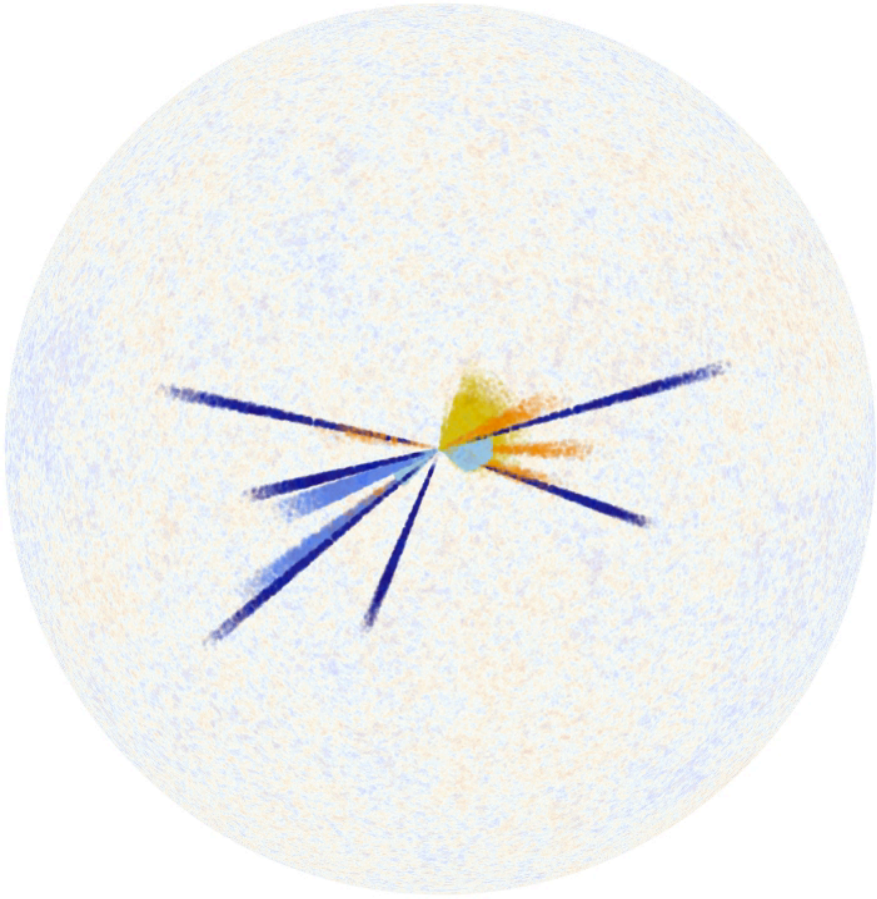
- *Dark Energy* and *General Relativity* constraints by measuring cosmic expansion history and growth of structure:
  - **Weak Lensing**: Photo-z calibrations and characterize the foreground
  - **Galaxy Clusters**: Redshifts and velocity dispersions of Galaxy Clusters
  - **BAO and RSD**: LRGs, ELGs, AGN, Lyα forest
- Concentrate on redshifts z<~1 and z>2.4 to complement Euclid



Galaxy evolution - VST & VISTA

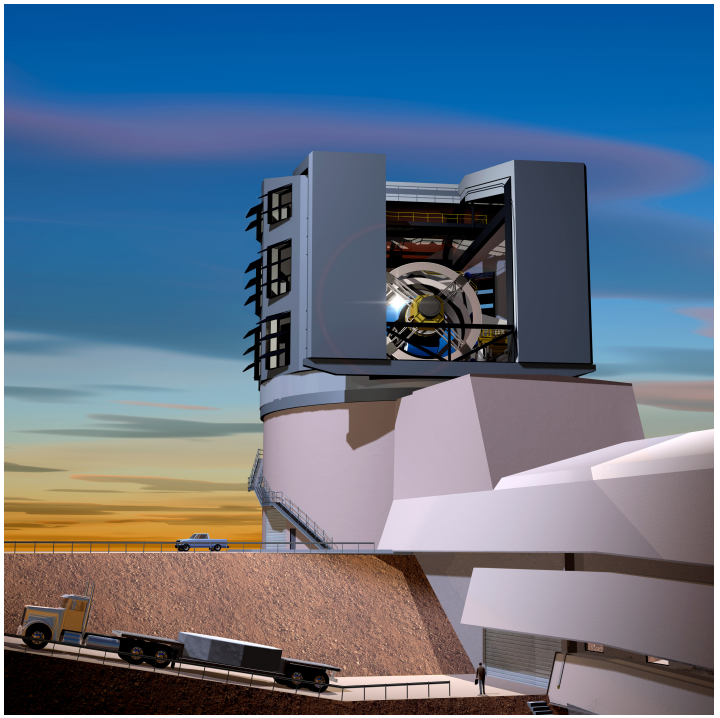
- Galaxy formation to dwarf satellite scale, halo occupation
- Evolution of mass & energy budget for z<1
- Growth of structure on 1kpc-10Mpc scales for z<1





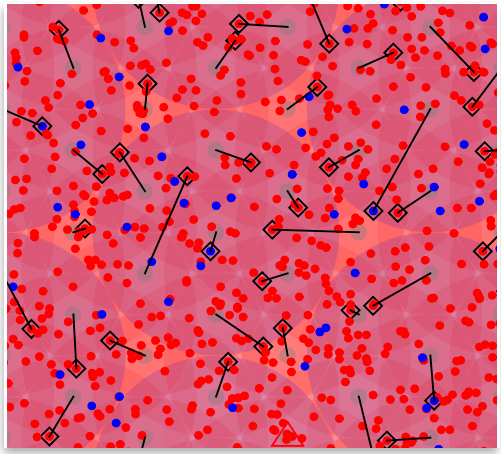
Transients - LSST

- Rapid classification of unusual live extragalactic transients.
- Host galaxy redshifts for Type Ia supernovae so that they can be used as cosmological distance indicators
- AGN broad emission line reverberation mapping experiment.



Generalities / Requirements

- MOS surveys covering a hemisphere in 5 years
- Consortium (“GTO”) and Community surveys
- Integrate into ESO operations model
- Parallel survey execution for efficiency
- 10s of millions of spectra
- Public surveys



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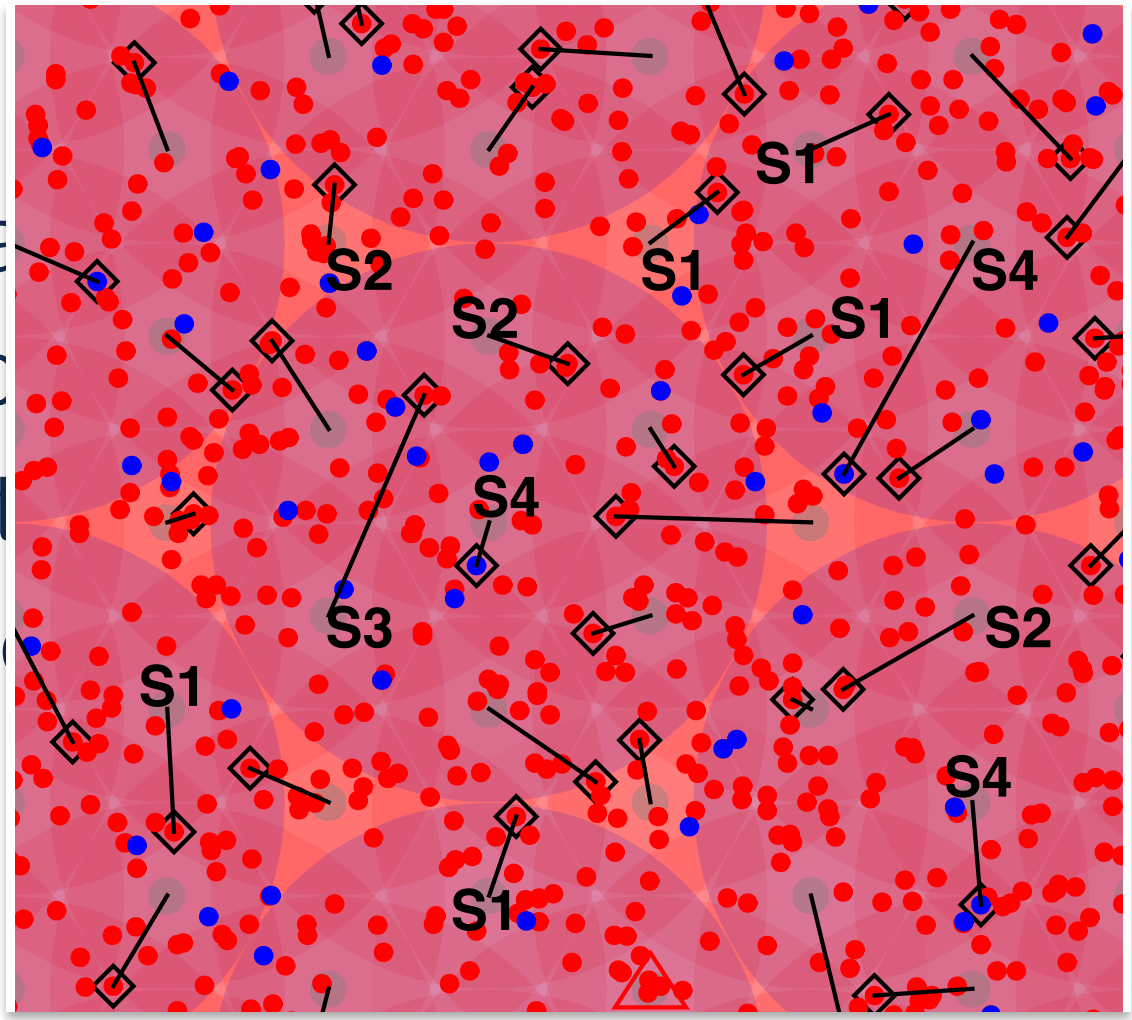


Requirements analysis

- Parallel execution means
  - Common observation preparations
  - Common selection function computation
  - Cross-talk on CCD, sharing of 1D spectra
- Survey sizes and duration mean
  - Automated observation preparation and data reduction
  - Accurate survey simulations for planning
- ESO instrument means
  - Use of ESO procedures (Phase 1,2,3, interfaces, structure)
  - ESO oversight must be possible

Operations basic concepts

- All participating surveys collaborate in the **Science Team** for science infrastructure
- Consortium **Operations Group** takes over tasks normally carried out by scientists
- **Progress reporting and survey strategy parametrization** allow ESO to exercise oversight

Science Team

- All members of all surveys (community and consortium)
- Governed by common policies (e.g. Science Coordination Board, all survey PIs, one vote per survey)
- Full sharing of all Level 1 data products
- Pool resources for Infrastructure Working Groups and delegate to operations group
- Surveys keep individual responsibility for delivering higher level data products to ESO
- “Non-participating surveys” also possible, but do not share in Science Team know-how

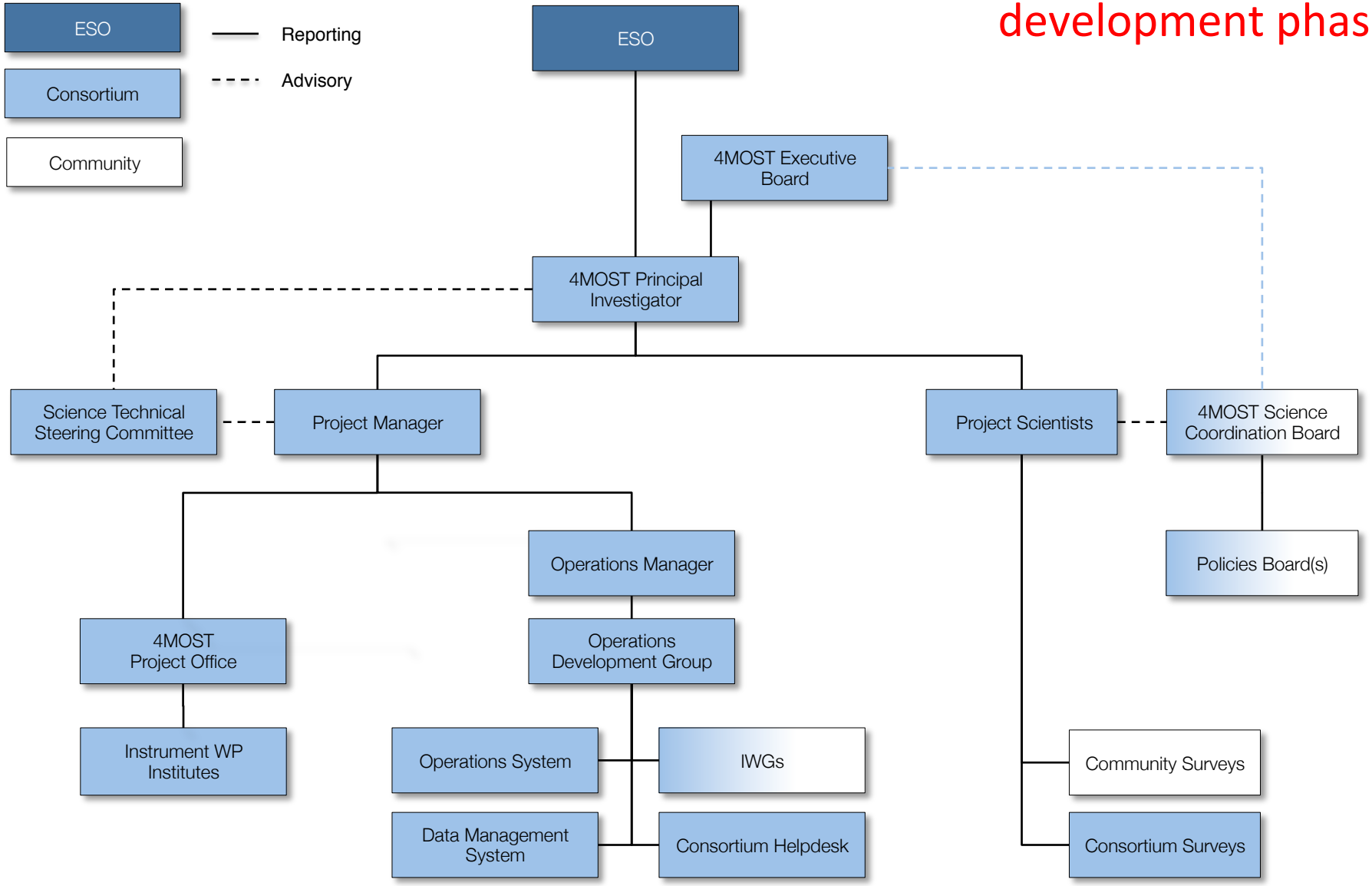
Consortium operations group

- Operations Management (@AIP)
  - Overall management
  - Systems Engineering
- Operations System (@MPE)
  - Operations simulations / survey strategy optimization tool
  - Observation preparation / progress tracking and reporting
- Data Management System (@IoA)
  - Data Reduction to L1 (includes QC pipelines)
  - Data Management and Archiving
- Helpdesk (@AIP)
  - Back-office for ESO User Support Department
  - Direct support of Science Team members
- Communications (@Hamburg)
  - Projects and paper handling

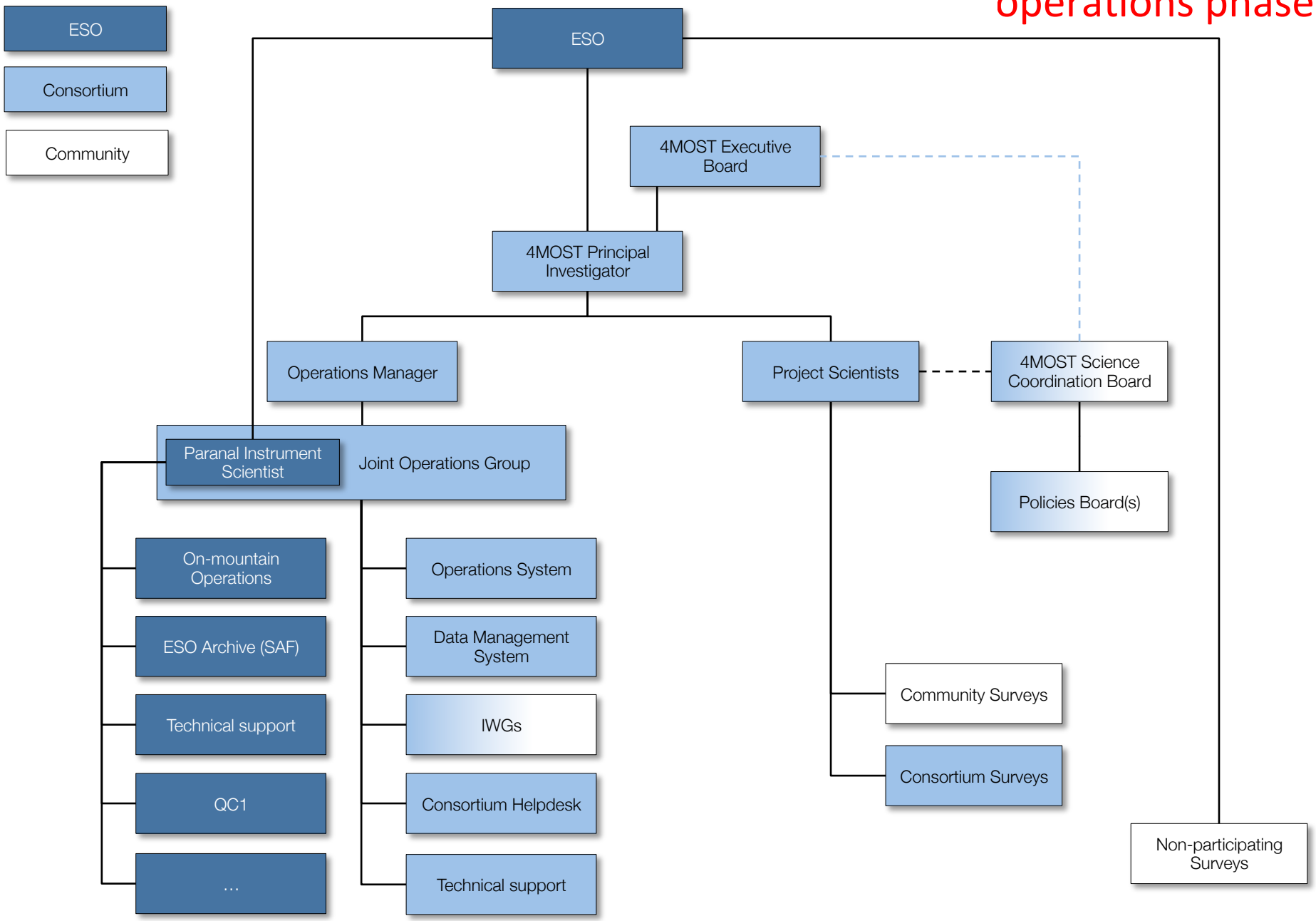
Infrastructure Working Groups (IWG)

- IWG2 Survey strategy
- IWG4 Selection functions (L2)
- IWG7 Galactic pipeline (L2)
- IWG8 Extra-galactic pipeline (L2)

development phase

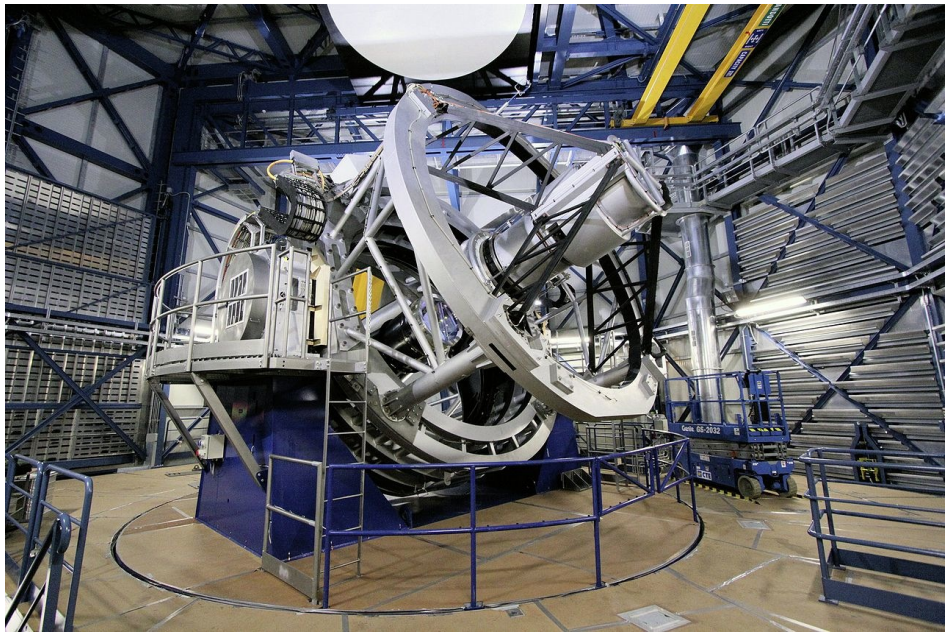


operations phase



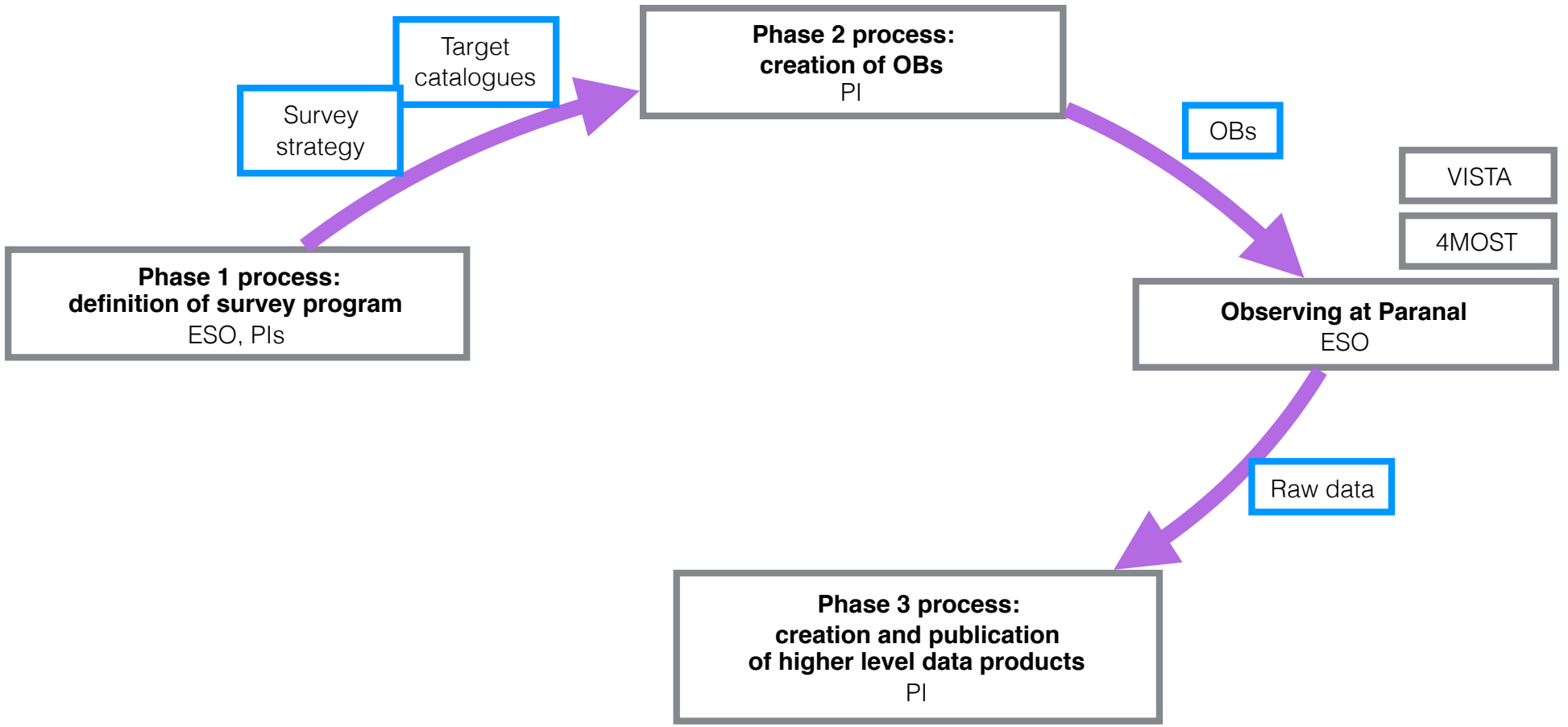
ESO provides

- On-mountain operations
  - Observing
  - Health checks and maintenance
- Public archive
  - Raw data, L1 data, L2 products
- Phase 1
  - Proposal handling and selection
- Oversight
  - Survey strategy and inter-survey priorities (phase 1)
  - Progress verification and “bad cop”
  - Final escalation instance for surveys unhappy with SCB decisions

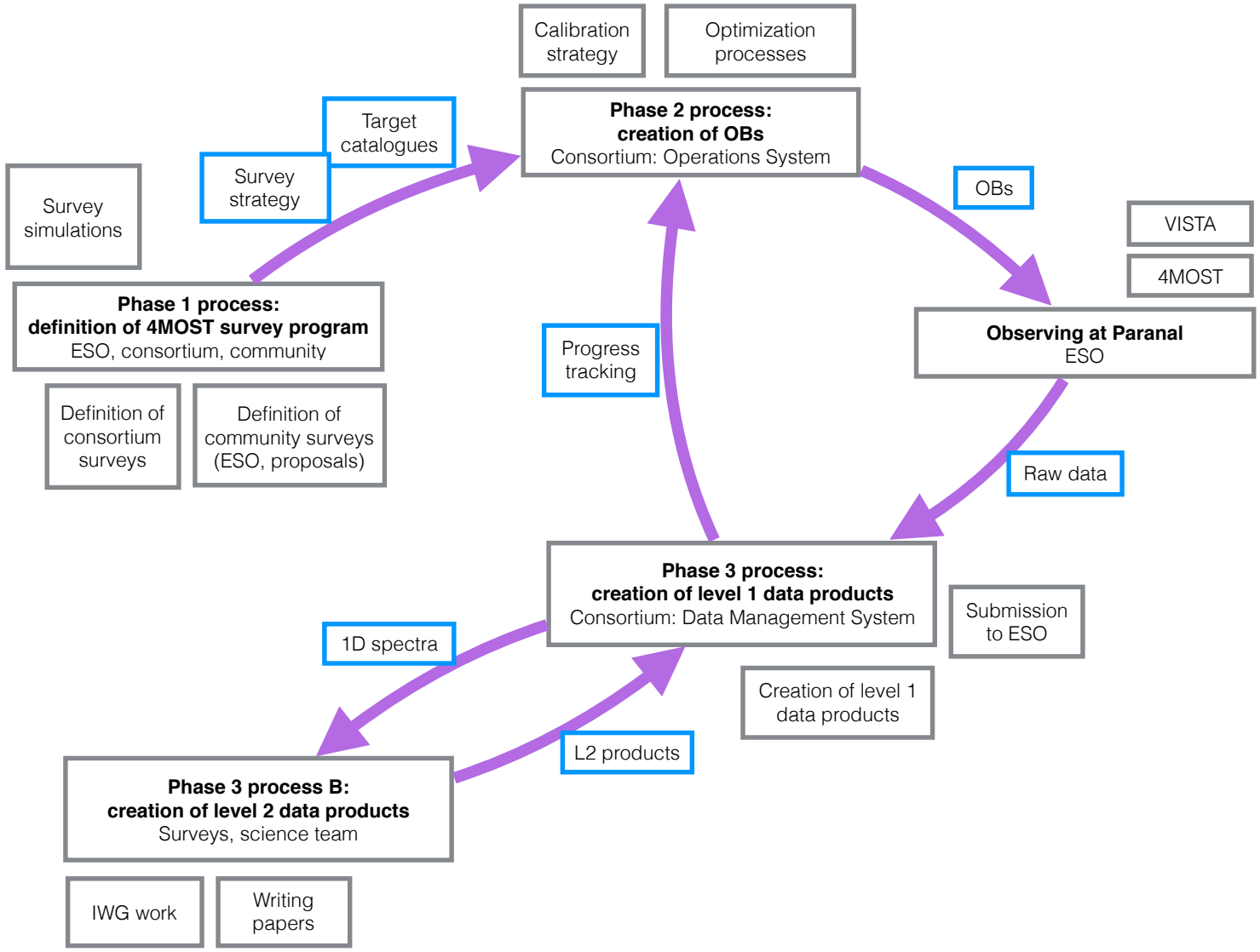


VISTA telescope

ESO operations model (AFAIK)

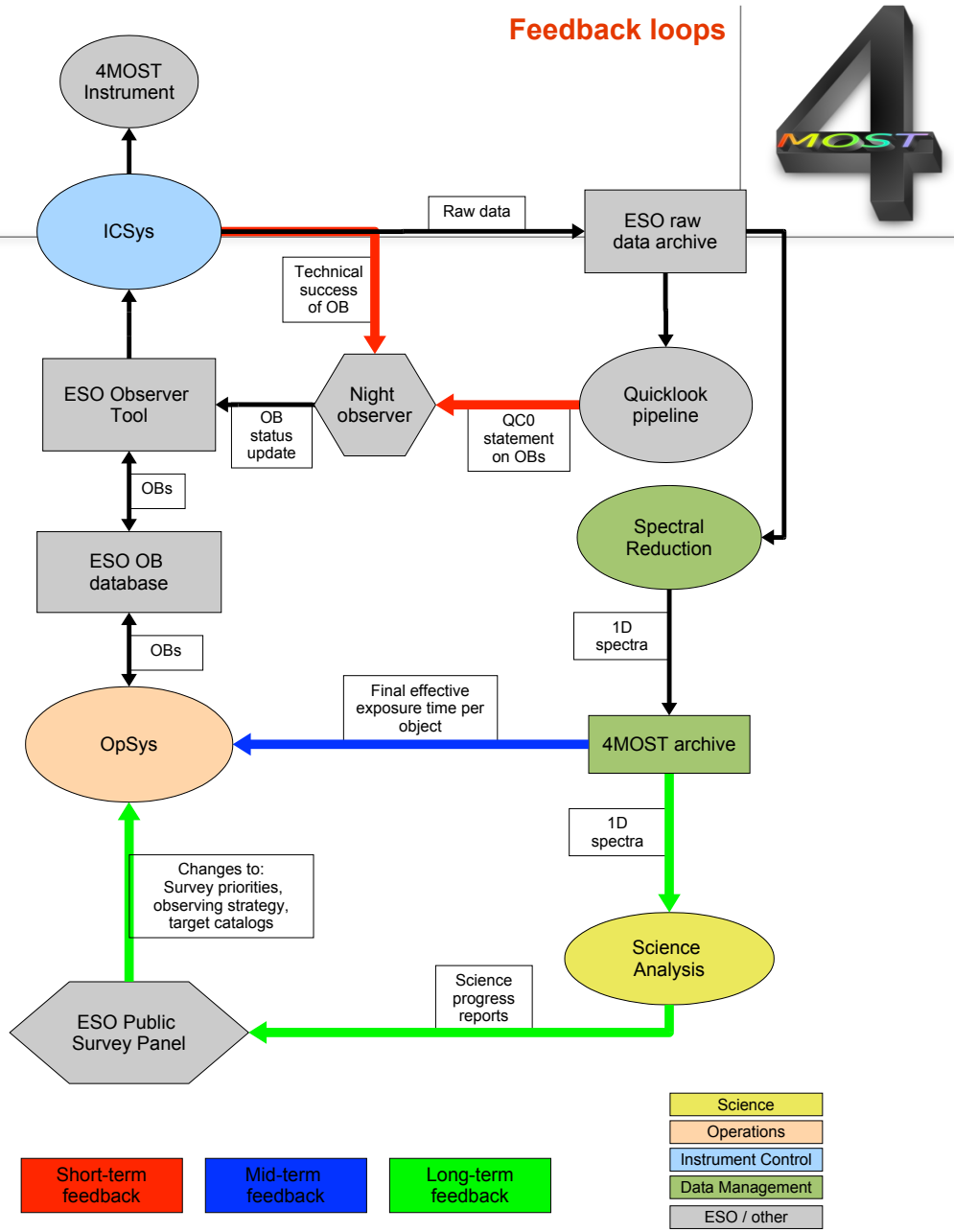


4MOST operations model



Feedback loops

- Short-term on mountain: instrument and observations are OK **(QC0)**
- Mid-term by OpSys: observational progress as expected **(progress DB)**
- Long-term by ESO / Science Team: science progress as expected **(review process)**



Current status

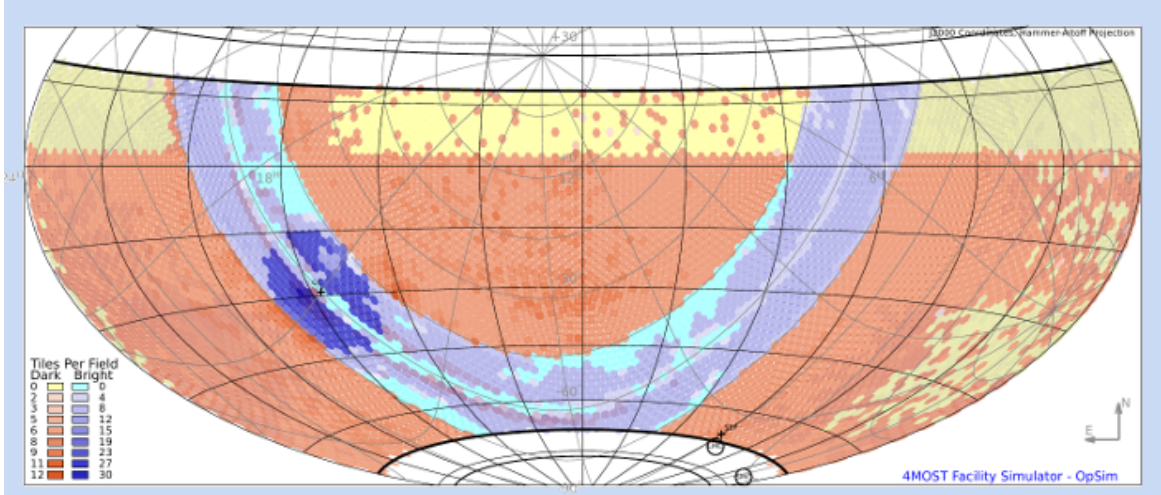
- ESO requirements summarized in Operations Statement of Work and Technical Specification
- Operational requirements from surveys still being processed (time links, target catalogue updates, etc.)
- Operations reviewed at Data Flow Design Review
  - Change in structure, responsibilities clarified
  - Authority of Operations Manager formalized
- Next milestones:
  - Final Design Review (Apr 2018)
  - Call for Proposal Readiness Review (Mar 2019)
  - Preliminary Acceptance Chile (Nov 2022)

Challenges in development

- Obtain operational requirements from science team and iterate them to perfection and feasibility
- Agree on sharing of responsibilities and implementation between ESO and consortium
- Draw up operations structure at once, instead of iteratively

Operations System

Problem: optimize parallel execution of 20+ surveys with distinguishable execution requirements



- Key feature is realistic survey simulator to optimize survey strategy (incl. seeing, northern wind, etc.) - possibly transferable
- 4FS-ETC will allow exposure time determination for massive amounts of template spectra
- Observation Blocks produced by OpSys for everyone as a service

Survey strategy optimization

- Need common sky areas, exposure times, avoid disturbing each others selection functions
- “IWG2 Survey Strategy” is Science Teams’ resource for making those compromises ➜ Consortium Survey Strategy made public with Call for Letters of Intent
- During Phase 1 community surveys join: synergies vs. independent science goals??
- Outcome of Phase 1 HAS to be an agreed survey strategy based on scientific criteria that OpSys implements “without thinking”
- But what will we learn in the first year of operations? How long do we wish to optimize survey strategy? Who approves changes?

Data Management System

- Raw data public immediately, L1 data public ~yearly, pipeline not (“only” documentation made public)
- Public archive at ESO and at consortium - coordinated approach important
- On-going discussions: short feedback cycles for observing progress (redshift success and transient classification). Need realistic efficiency gain predictions.

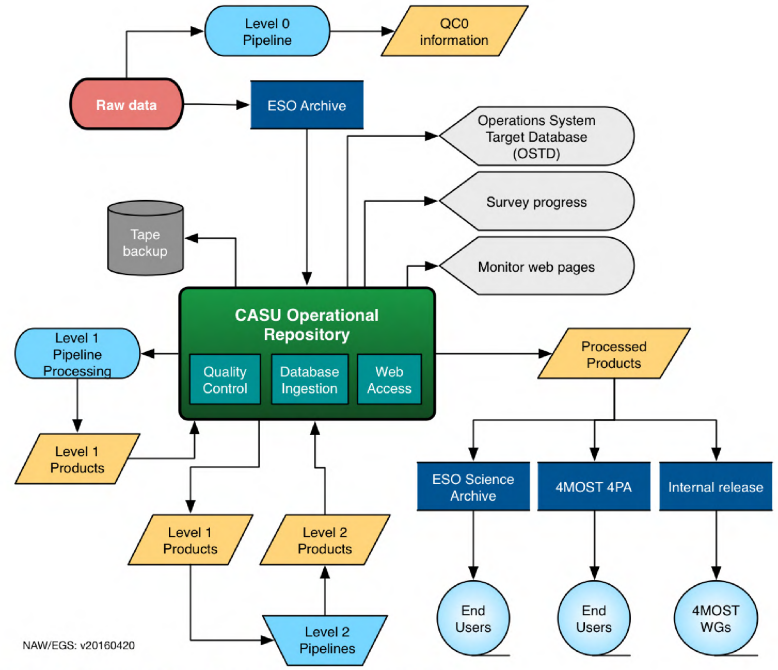


Figure 2 Schematic of the end-to-end data flow envisaged for the DMS

Infrastructure Working Groups

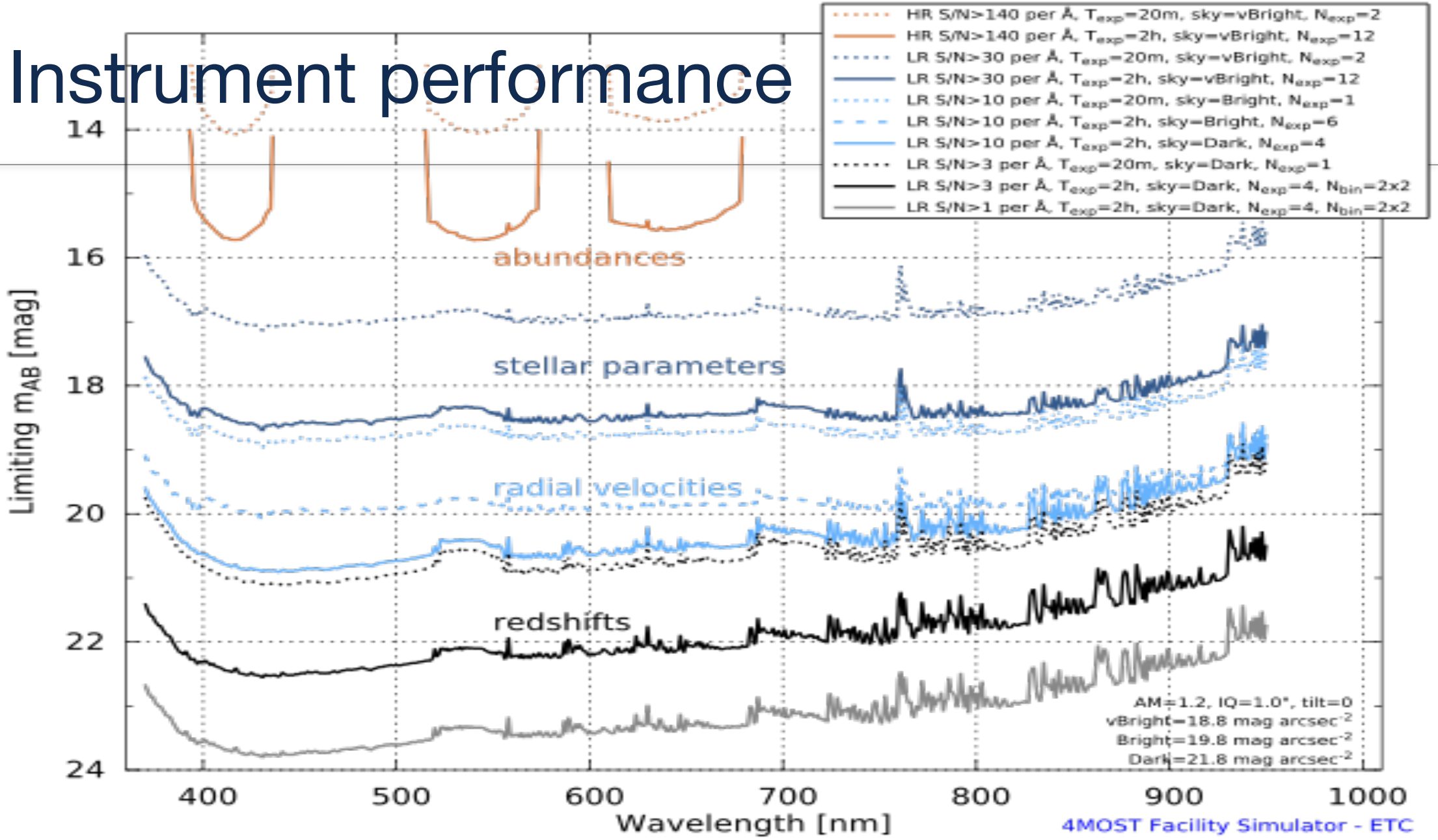
- Produce critical software:
  - Galactic pipeline (velocities, abundances)
  - Extra-galactic pipeline (redshifts, line fluxes)
  - Selection functions (targeting+success probabilities)
- Partially resourced from “postdoc good-will”
- Unclear whether obtaining professional software with RAM specification is realistic, software product assurance is an open topic

Summary

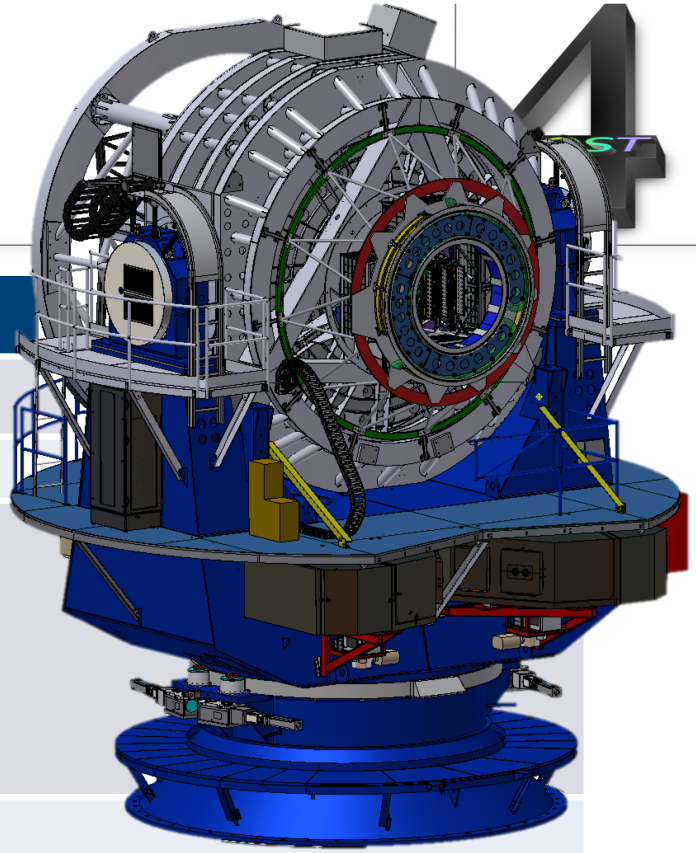
- 4MOST will enable a parallel execution mode for spectroscopic survey operations.
- The challenges are understood and solutions are known.
- The complexity of the task of survey planning may seem daunting at times.
- 4MOST may serve in the future as a reference for how ESO may run large surveys with dedicated telescopes.


4MOST

Instrument performance



Instrument specifications



Specification	Design value
Field-of-View (hexagon)	~4.1 degree^2 (⌀>2.5°)
Multiplex fiber positioner	2436
Medium Resolution Spectrographs (2x) # Fibres Passband Velocity accuracy	R~4000–7500 812 fibres (2x) 370-950 nm < 1 km/s
High Resolution Spectrograph (1x) # Fibres Passband Velocity accuracy	R~20,000 812 fibres 392.6-435.5, 516-573, 610-679 nm < 1 km/s
# of fibers in ⌀=2' circle	>3
Fibre diameter	⌀=1.45 arcsec
Area (first 5 year survey)	>2h x 18,000 deg^2
Number of science spectra (5 year)	~75 million of 20 min