PLATO Ground-based Observations Programme

- Goal / Needs / Organisation
- Interfaces / subsystems
- Ongoing activities / Milestones
- Science activities

Scientific Objectives 1-7

S1 - Determine the bulk properties (M, R and mean ρ) of planets in a wide range of systems (including HZ Earths)

S2 - Study how planets and planet systems evolve with age

S3 - Study the typical architectures of planetary systems

S4 - Analyse the correlation of planet properties with stellar parameters (e.g., stellar metallicity, stellar type)

S5 - Analyse the dependence of the frequency of terrestrial planets on the environment in which they formed

S6 - Internal structure of stars and how it evolves with age

S7 - Identify good targets for spectroscopic follow-up measurements to investigate planetary atmospheres

The Ground-based Observation Programme (GOP)

The PMC is responsible for organising and executing the ground-based (and space) follow-up observation programme. This includes

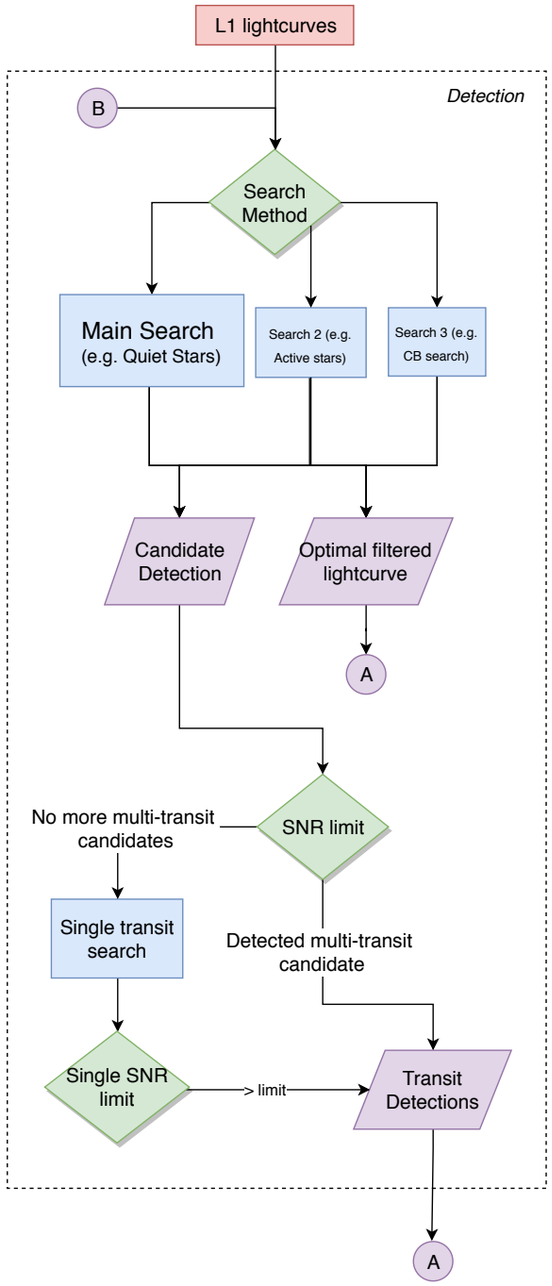
- candidate mimic determination and radial velocity measurements as follow-up observations
- as well as any preparatory observations needed
- The GOP will also look beyond the immediate PLATO requirements for further observations (ground- and satellite-based)

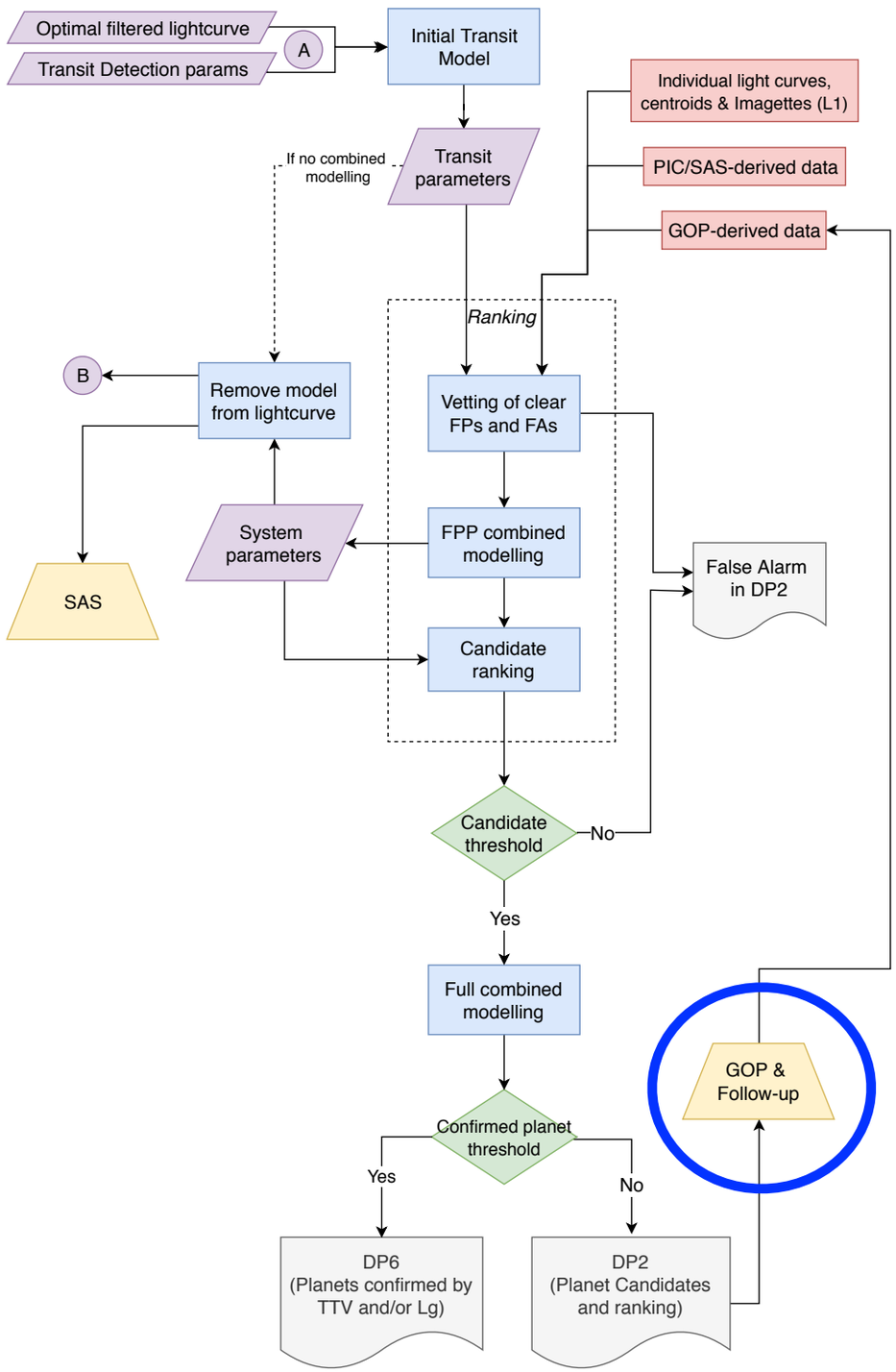
Vetting

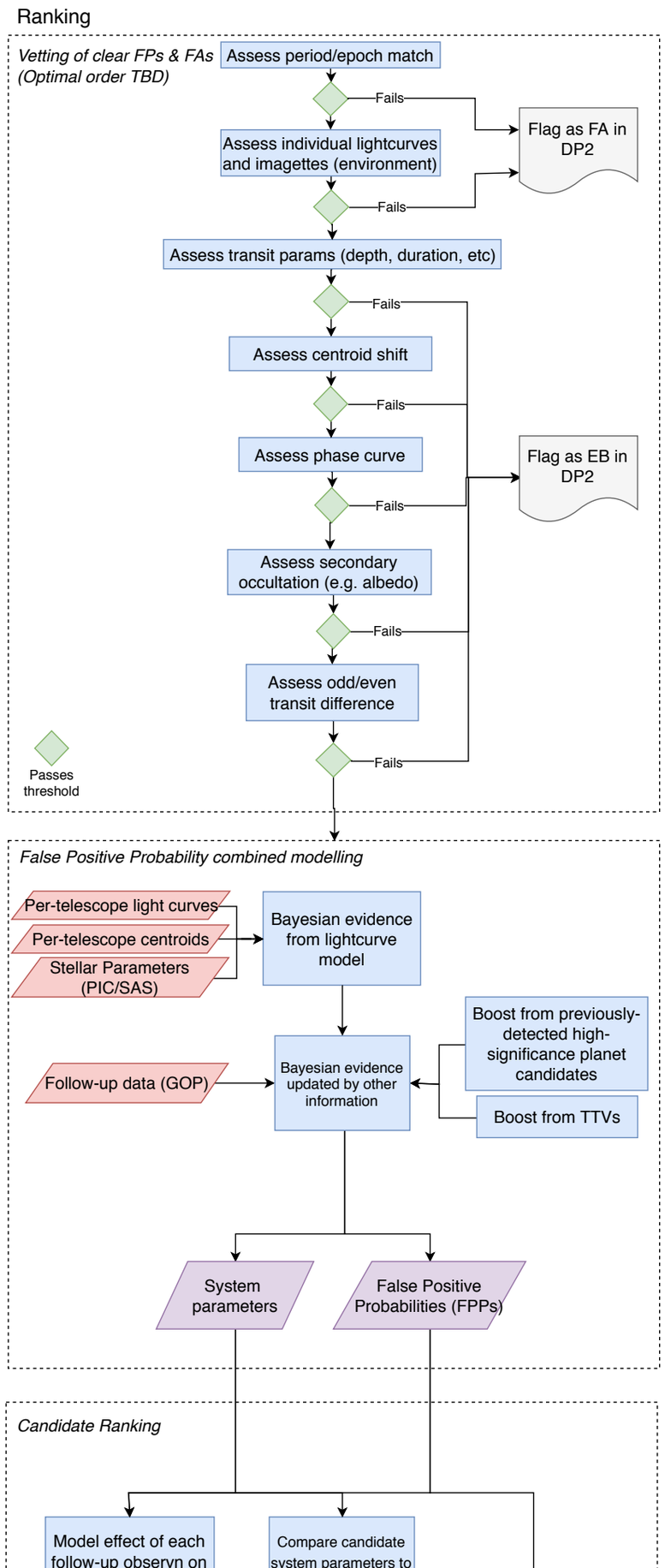
Masses

GOP organisation is defined taking advantage of lessons learned from previous space missions (CoRoT/Kepler/K2/TESS) – this includes interfaces with the project computing infrastructure (exoplanet & stellar pipelines) and database system.

GOP somewhere in a complex series of activities…







(Santerne et al.)

Exoplanet pipeline (EAS)

Stellar pipeline (SAS)

Same role of GOP

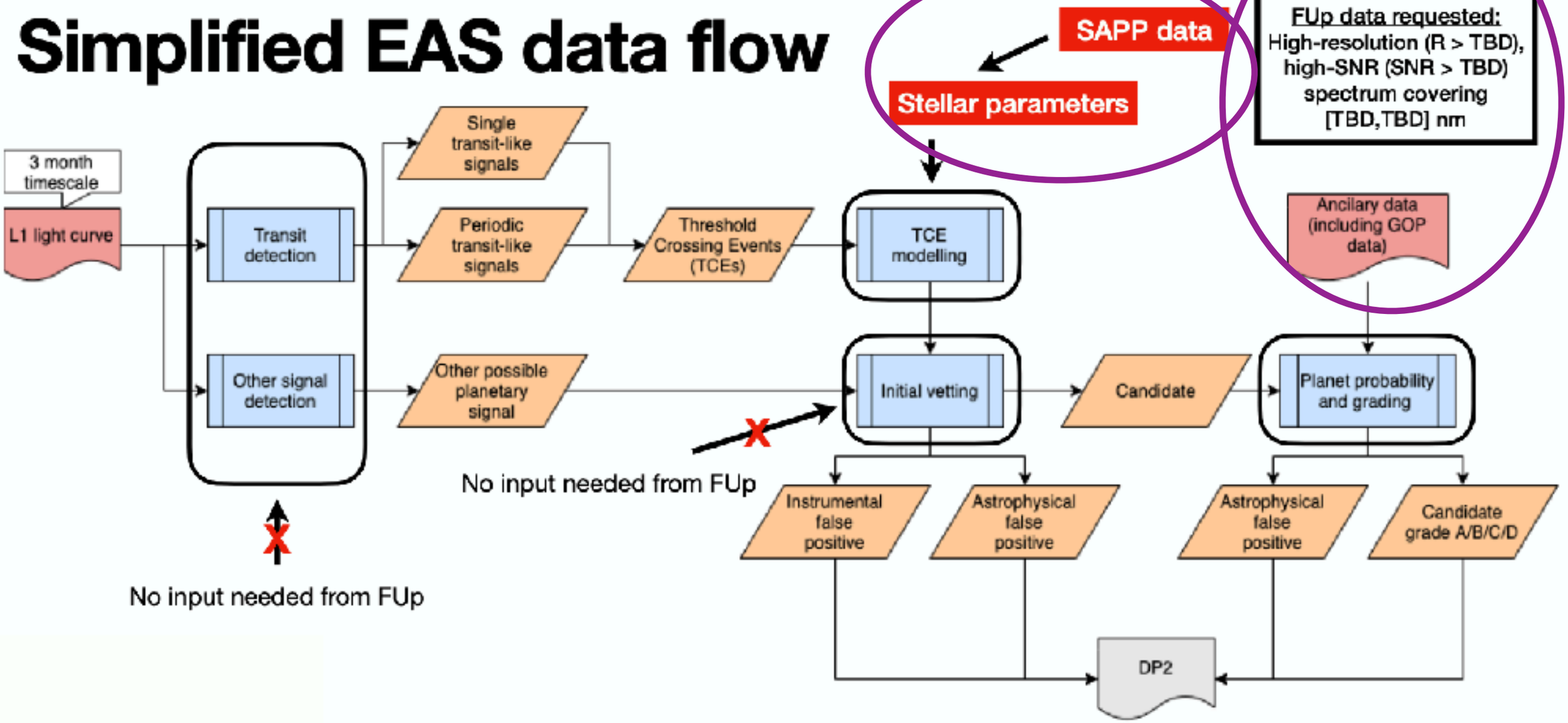
+ for stars without transiting planets

Role of GOP: provide observations for

1) discarding false positives + ***2) measuring precise masses*** + ***3) stellar parameters***

GOP

Simplified EAS data flow



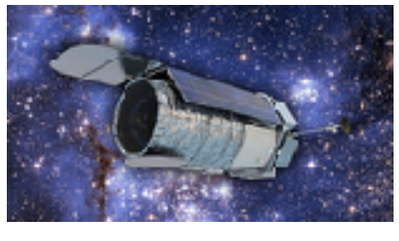
GOP: science+vetting needs

1. Basic stellar parameters
   - coordinates, mag, spectral type, mass, radius, age…
   - specific for the reduction pipeline: star RV
   - … others ?
2. System properties: environment
   - binarity, known planets and their parameters
   - contaminants
3. Best radial-velocity measurements
   - vsini, activity level (RV precision, choice of instrument)
   - optimised scheduling
4. Time series from previous obs/surveys (with uncertainties)
   - RVs: known or long-P planets
   - Activity proxy: star-planet disentangling

=> in PIC

=> in PFU-DB database

=> + existing archive data

(From surveys: Gaia, TESS, RVs, etc)

GOP will provide

- High resolution, high S/N spectra: v*sin*i, Fe/H, Teff, mean activity level (various indexes)
- Time series with BJD, RV, Sig_RV, CCF bisector, activity index, …
- Radii from interferometry

GOP: goals and tasks

GOP = “Follow-up arm” of the mission for the prime sample & core science questions

Main input for the science goals:

- Establish the nature of the transit events and identify/reject false positives
- Characterise the planet properties (M, ρ, e) from Earth to giant planets as well as planetary system properties (statistics/architecture)
- Help correct for contamination effect (e.g. radius estimate)
- Help for the determination of stellar parameters

Tasks:

- Design and implement an efficient organisation of ground-based observations
- Insure availability of required observing facilities / help the development of new facilities
- Monitor available observing facilities
- Define benchmarks/validations for participating facilities
- Estimate the amount of telescope time required
- Prepare and coordinate needed observing time proposals (ESO, others,…)
- Coordinate available telescope time from participating members and perform observations for i) the prime sample and ii) core science questions involving more than the prime sample
- Insure quality control of the data and provide the “Lg” data to the PFU-DB (PDC)
- Monitor the progress of the ground-based observations (update the organisation or corrective maintenance if needed)

Follow-up organisation of the work

- Large number of expected transit candidates
  => systematic observation of all transits with large telescopes unfeasible
  => an optimised follow-up scheme has to be organised
- Same level of precision cannot be reached for all stars (spectral type, luminosity class, activity, brightness)
- Same is true for the RVs and high-contrast imaging
- Strategy for the follow-up: efficient approach
  => matching targets and adequate facilities (avoid useless observations)
  => minimum number of used facilities per target (avoid inefficient duplications)

In practice => a “guided” multi-step approach from moderate to high-precision (screening)

=> need to design and develop tools (WP141):
- automatic distribution of targets in boxes according to their needs
- optimum match between participating facilities and target needs (boxes)
- efficient interface between observers and target information (PIC, PDC-PFU)

+ optimisation of scheduling

GOP-PDC connection

PDC

Pipelines
EAS
SAS

PLATO
Data

PIC

Pipeline
PDC-DB

PDC-DB

PFU-DB

+ GOP data

Only interface
of the GOP
with the PDC

PSM

GOP

1

Scheduler

3

Information/data
base

Observation type
determination

2

Quality control
system + ?

4

FU center

Internal interface
between
FU center & facilities

Facilities

Observer

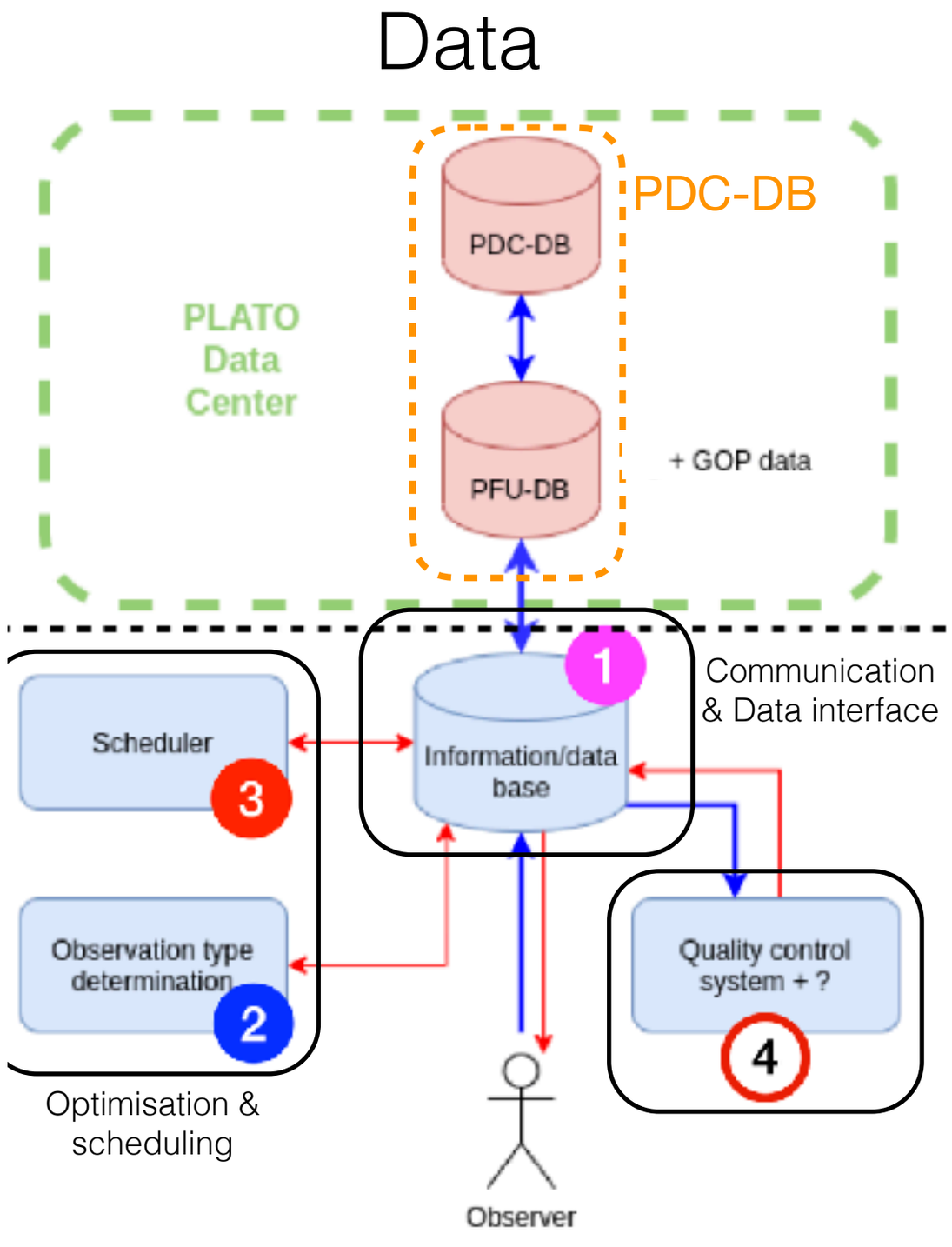
Data + information

Information

Subsystems

PDC

PSM



on-going work

Summary

Centre

Subsystem group

Subsystem

Component group

PSM

Ground-based Observation Programme (GOP)

Communication & Data Interface (GOP-GCDI)

Optimisation & Scheduling (GOP-OPS)

Quality Control System (GOP-QCS)

Internal communication and storage

Repository (GCDI-REP)

Observer interface (GCDI-OBI)

PFU Interface (GCDI-PFI)

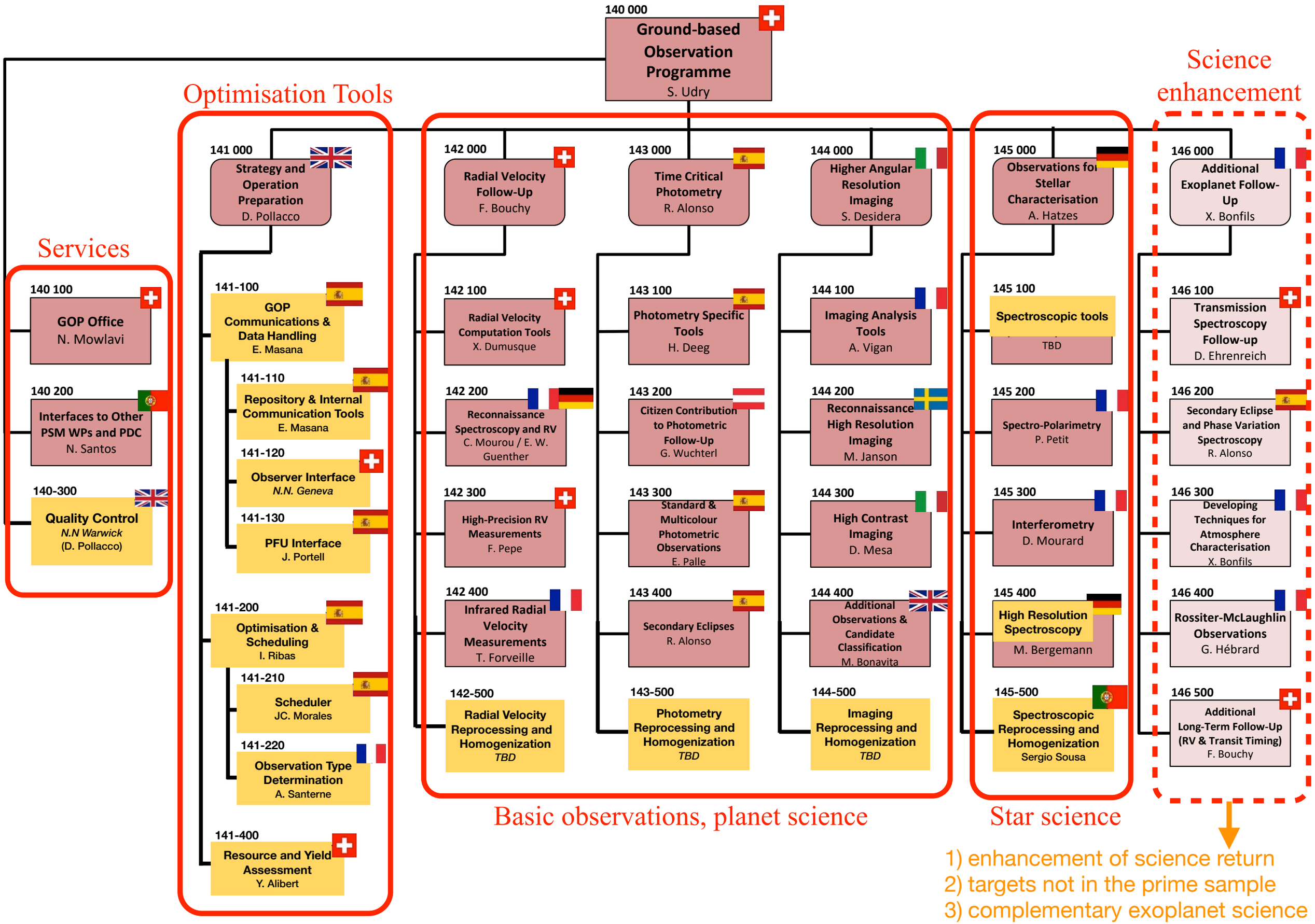
Observation type determination (OPS-OTD)

Scheduler (OPS-SCH)

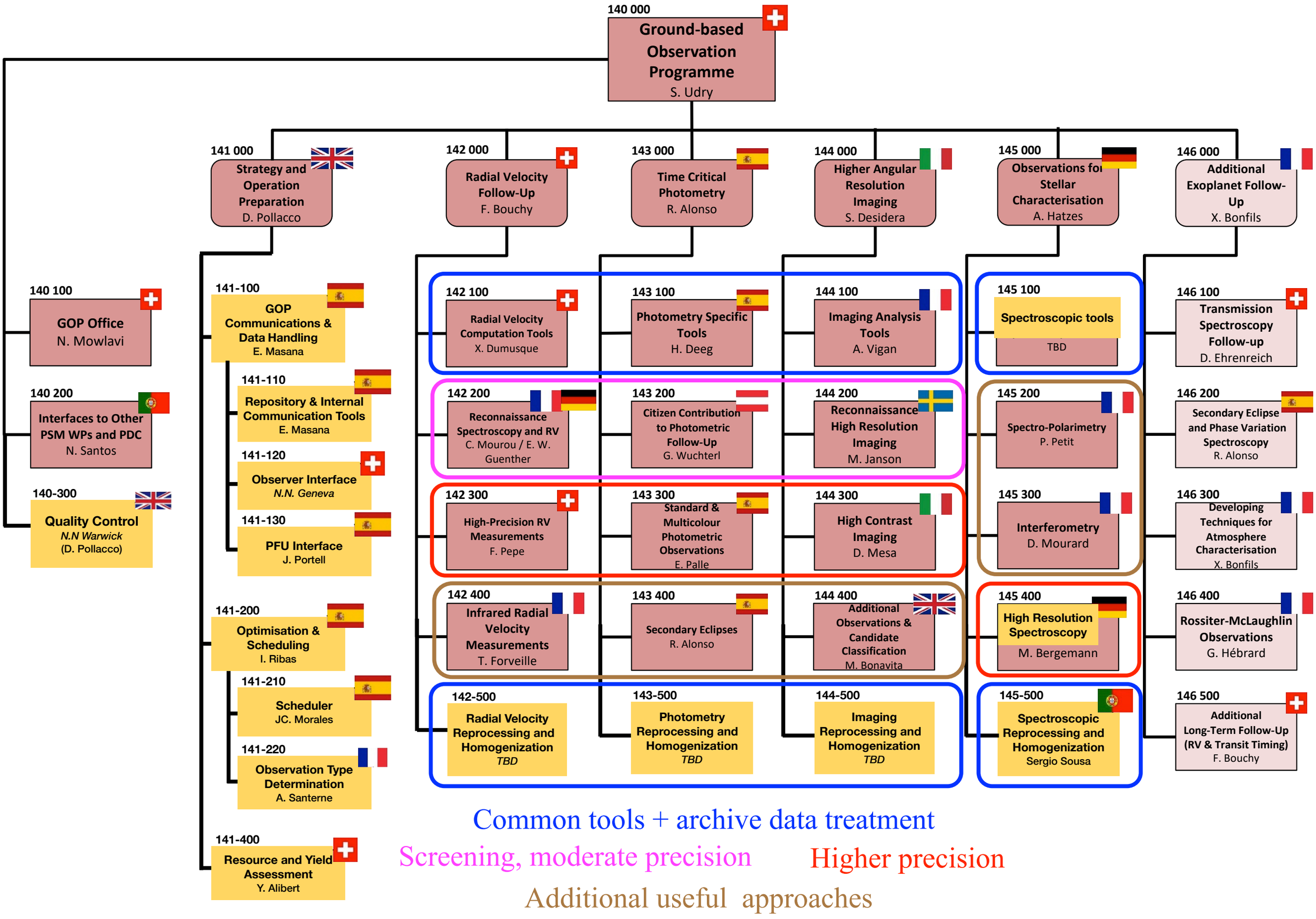
automatic scripts

human control

- **Organisation chart**



- **Organisation chart**



Ongoing GOP-specific tasks

=> for each type of observations (spectro, photom, imaging, …)

- **Interfaces/Data formats**
  - PFU-DB data description

Data format to be chosen (FITS, HDF5, other)

ongoing

- **Facilities**
  - List of facilities with parameters (ex: contact person, # of nights available, …)
  - Keep information on facilities in a local database (web interface)

- **Benchmarks**
  - Definition of criteria
  - Requirements on Data products (DRS)
  - Requirements on implementation of common tools

} starts now evolutive

- **Quality Control**
  - **At facilities level** (ex: cleaned data)
  - **At GOP level,** Obs. type specific (ex: SB2)
    - mainly automatic scripts
    - but unavoidable human control

- **Common tools (for facilities)**
  - Tool development
    - Identification / definition
    - Implementation
  - Choice of baseline tools and strategy
  - Archive data re-processing

} to be ready for E2E tests (2025)

now-2025

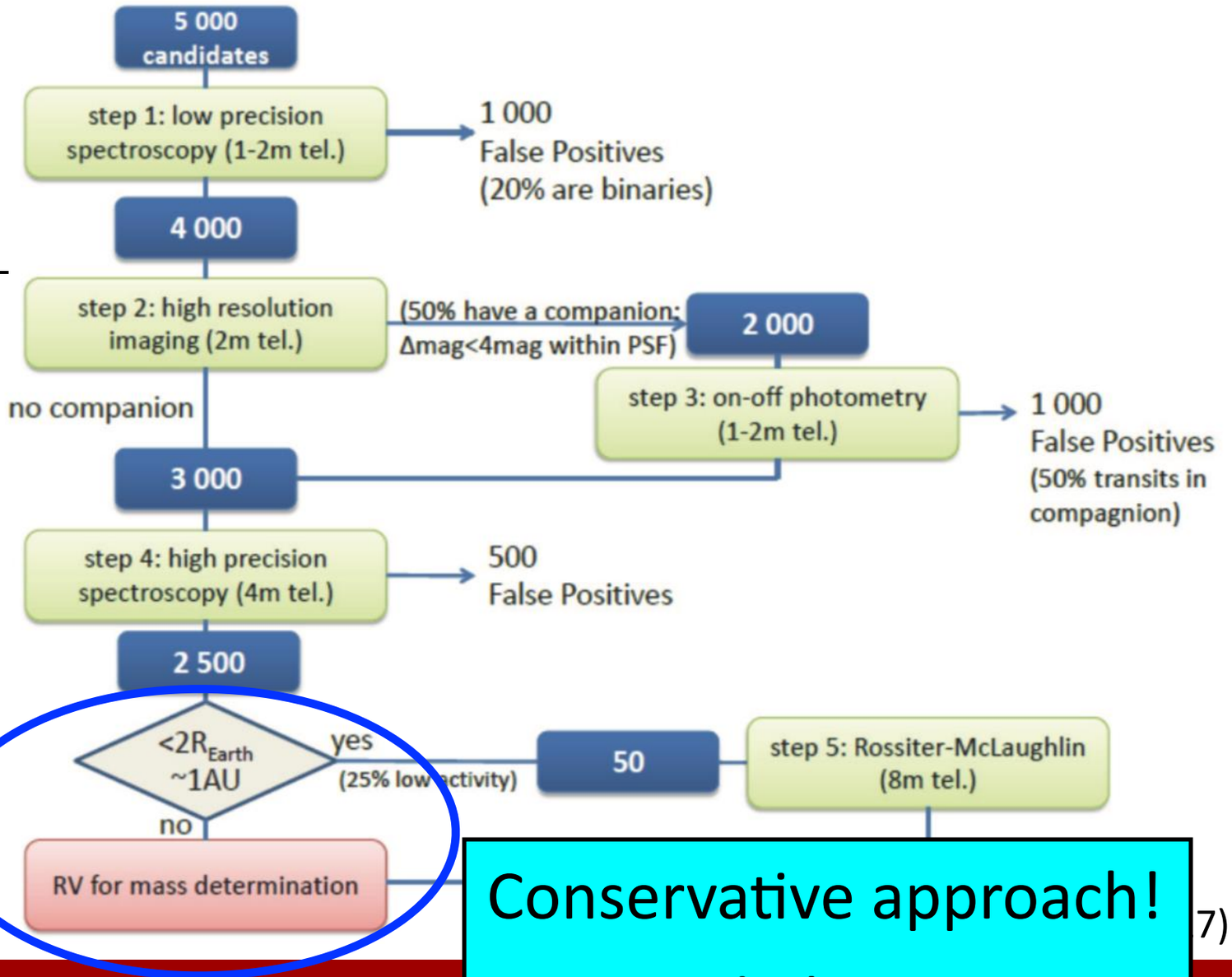
Telescope time estimate

PLATO follow-up

Procedure is well established: previous mission

Advantage: Gaia – both in input catalogue preparation and filtering

Eta-Earth not constrained by Kepler



Hierarchical approach

2-m class telescopes (10+)

4-m class telescopes (HARPS, HARPS-N, NIRPS, CARMENES, SPIRoU, +)

10-m class telescopes (ESPRESSO, +)

Conservative approach!

We can do better now

Telescope time estimate

Table 6.2: Estimates of ground-based telescope resources needed for follow up of planet candidates discovered during the PLATO Long-duration Observation Phase in both hemispheres.

Telescope Class	Filtering/Candidate Confirmation		Radial Velocity Measurements		Total Nights
	(nights/year)	(Total nights in 7 years)	(nights/year)	(Total nights in 9 years	
1-2 sp					
1-2 imaging					
1-2					
1-2 sp					
4m high-resolution spectroscopy	~20	~140	~100	~900	~1040
8m high-resolution spectroscopy	~5	~35	~80	~720	~755

Follow-up is tractable with existing/planned facilities with reasonable allocation of time

Follow-up activities include favouring the development of new facilities

Note 1: The time spans of 7 years for the filtering observations and of 9 years for the radial velocity observations are assumptions based on estimates of available telescope resources.

Note 2: The numbers reported in the Table are global for northern and southern sky visibility.

GOP activities

- Design and implementation phases:
  - define the approach: organisation and requirements for observation strategy
    (guided, optimised, multi-step approach: avoid duplication and non-useful obs.)
  - develop the needed tools for the operations phase
  - monitor and help the development of the facilities to perform the observations
  - support the theoretical developments to improve our ability to get extreme precision RVs
  - define requirements and benchmark observations for participating facilities
  - insure the link with the other activities in the PMC
- Operational phase of the mission
  - implement and run the optimised scheduling of the observations
  - actual observations with the various facilities
  - focus on the core science (prime sample)
  - insure that we meet the mission goals
  - quality check
  - help the community to exploit the legacy part of the PLATO results

=> needs to develop as well towards science-oriented activities

Thank you