NEOexchange: A Target and Observation Manager for NEO Follow-up

TOMs: Tools for science-driven observing programs in the LSST era

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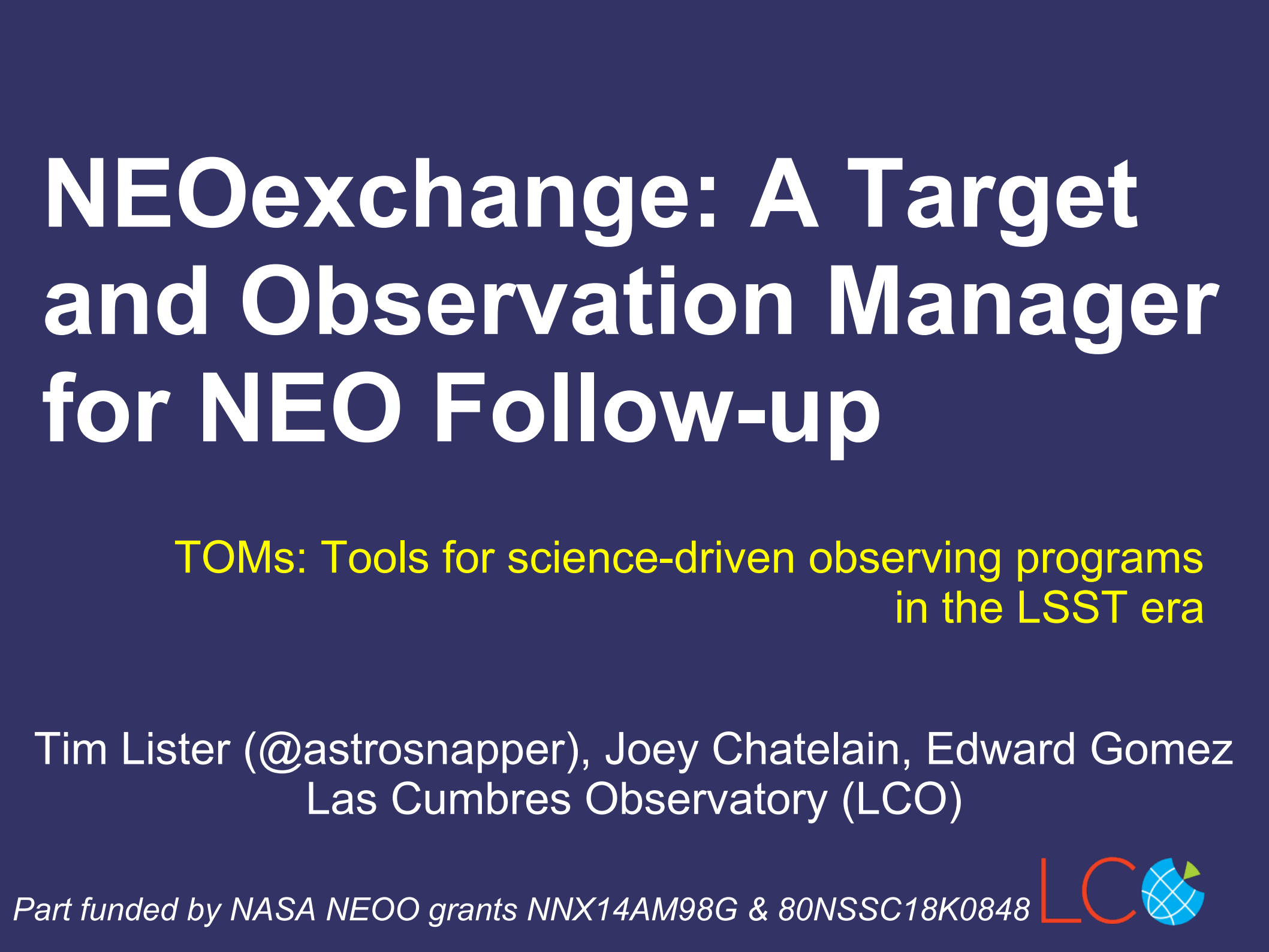
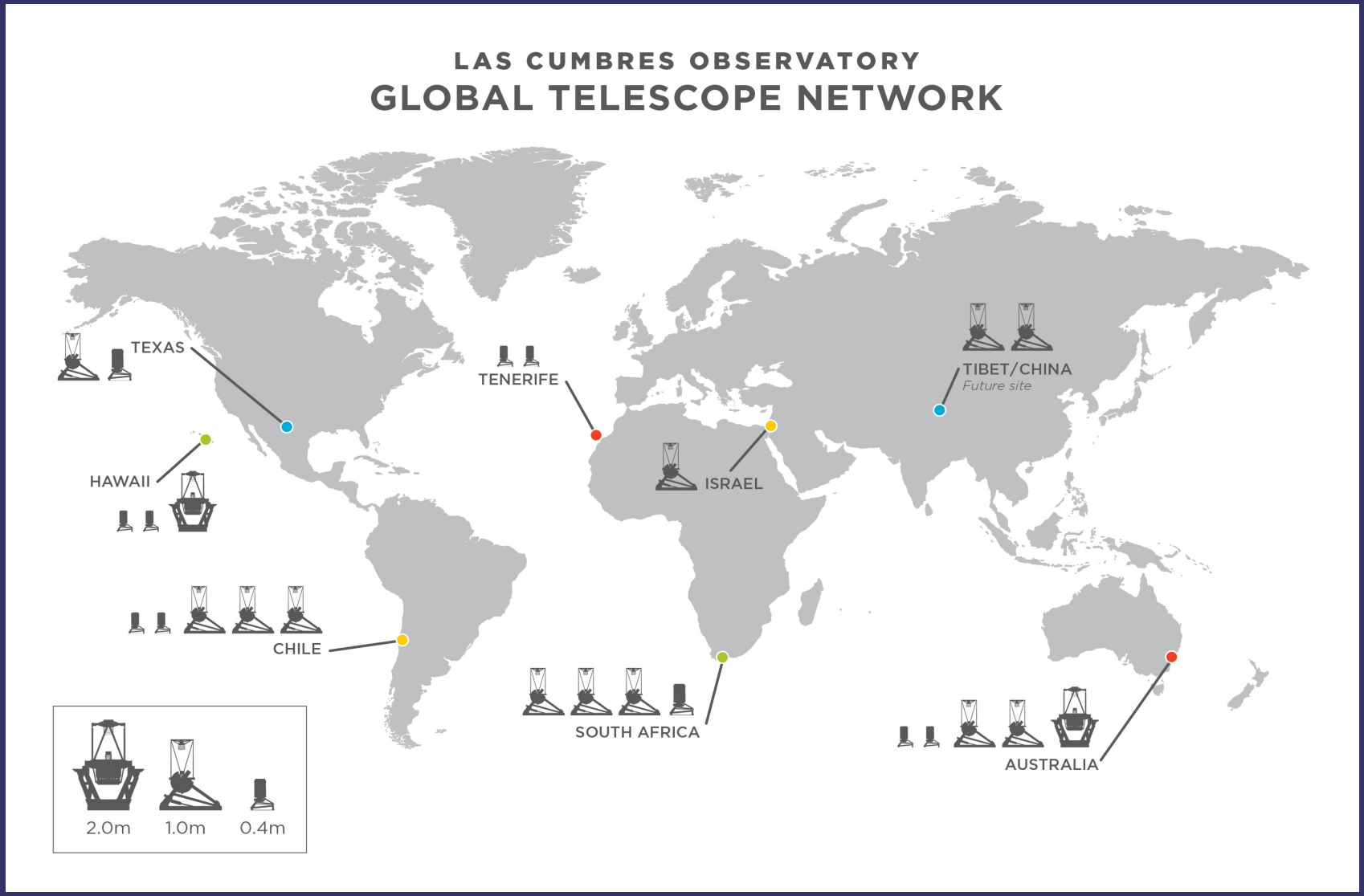
Part funded by NASA NEOO grants NNX14AM98G & 80NSSC18K0848



Overview

- The LCO Telescope Network
- NEO characterization efforts
- Discuss what are being called TOMs
- LCO/NOAO's plans for TOMs in general
- Our plans for NEO TOMs
- How a TOM could help with Didymos observation co-ordination

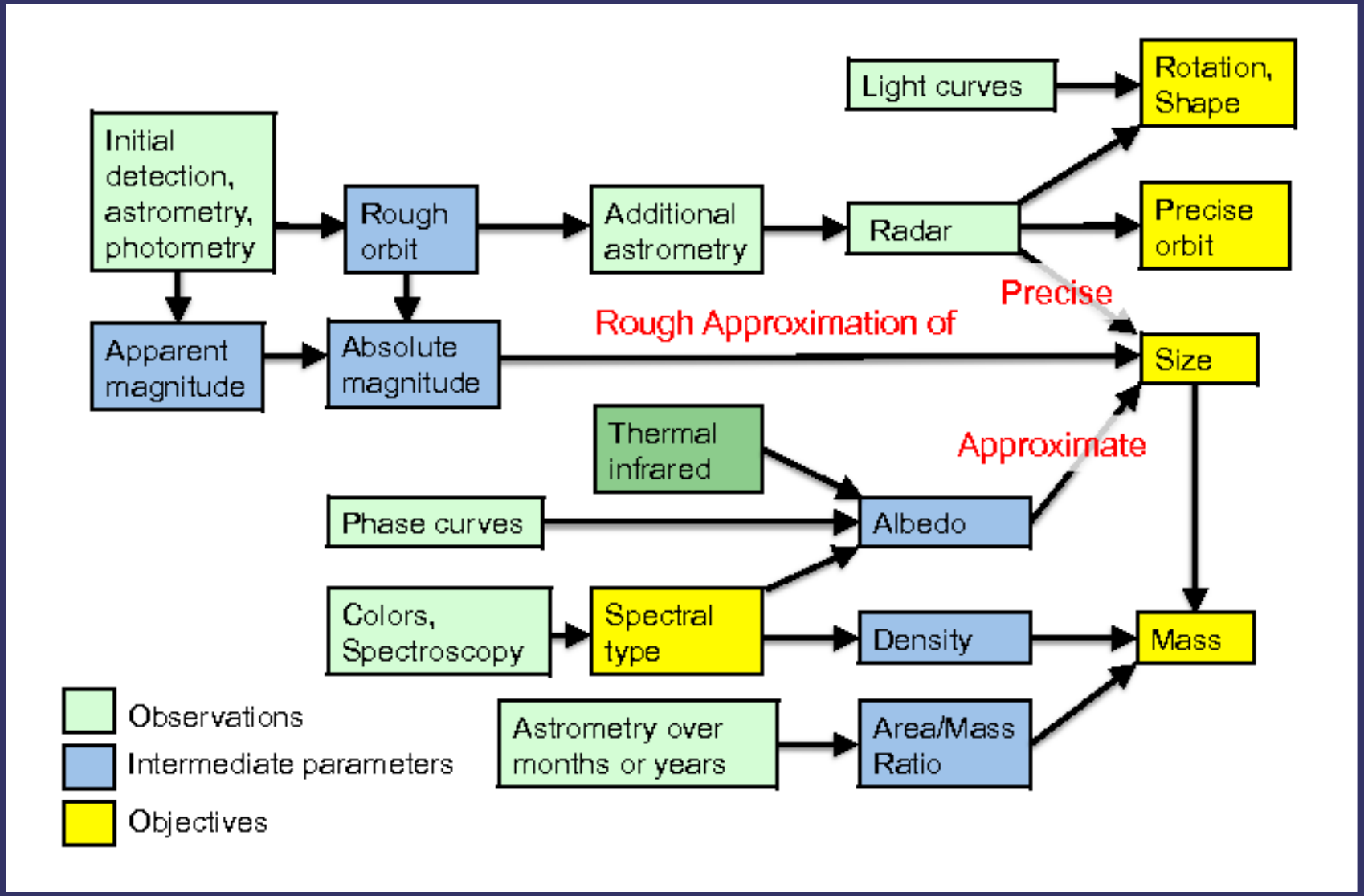
The LCO Telescope Network



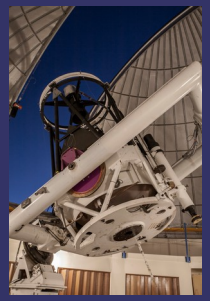
The LCO Telescope Network

- Network now consists of:
  - 2 x 2m telescopes (imager & low-res spectrograph)
  - 9 x 1m telescopes (imager & fiber-feed to high res. spectrograph)
  - 10 x 0.4m telescopes (imagers)
- 3 extra 1m telescopes funded and coming:
  - 1 to McDonald Observatory, TX (2019)
  - 2 to Teide Observatory, Canary Islands (2020)
- New, improved CCD controllers for the 1m imagers

Overview of NEO Characterization

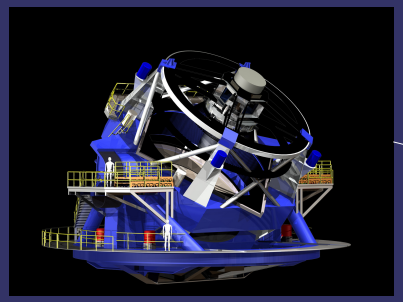


Follow-up observations coordinated across a range of facilities



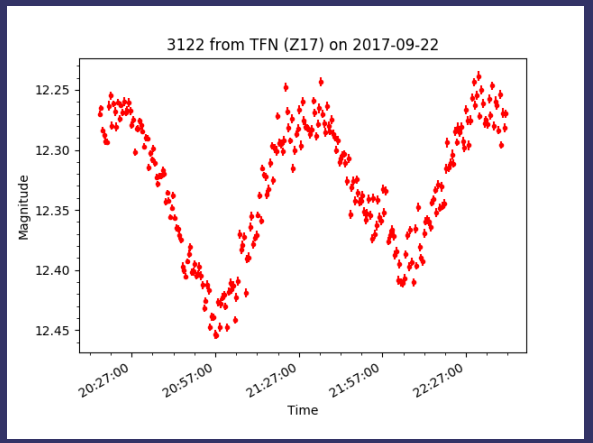
Eliminate non NEOs

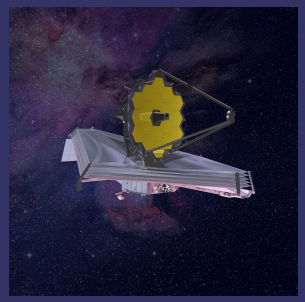
Initial Followup



Characterization

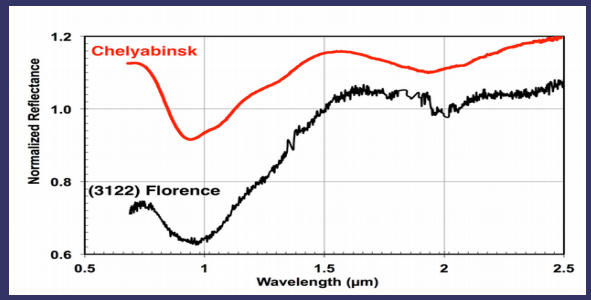
Photometry/Light curves





IR imaging/spectra
Spitzer/JWST

Radar imaging
Goldstone/Arecibo



Characterization spectra

Keeping track of follow-up: hard, going to get harder

Current follow-up programs take 1000s of observations and TB of data

Rapid alerts and rapid follow-up increasingly possible and desirable

Managing observations and data is already a major challenge and going to get worse

Need to co-ordinate multi-wavelength, multi-method campaigns on important targets (e.g. 67P, 2012 TC4, 46P, Didymos)

Future infrastructure needs to address this

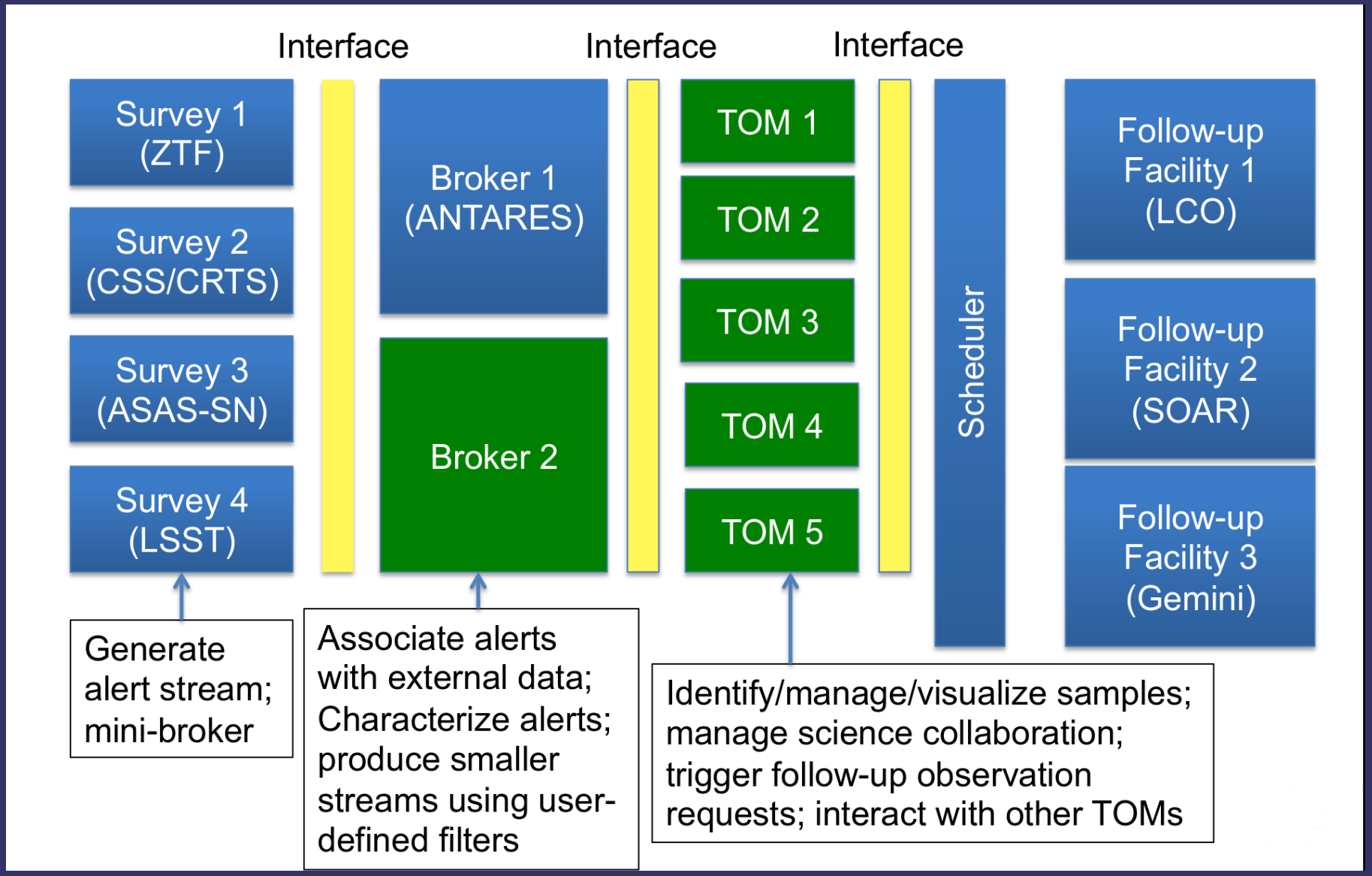
Goals of TOM Systems

- Coordinate programs where the workload of keeping track of targets, observations and data products would otherwise be onerous

- A framework for science-specific analysis to be conducted

- A framework to interact with external services
  - harvesting alerts, target and catalog information
  - submitting observation requests
  - obtaining feedback from telescope facilities
  - accessing data archives
  - coordinating with other TOMs

Role of a TOM in the Ecosystem



Role of brokers for Sol. Sys. objects is a little different as future surveys and ANTARES handle moving objects differently to other alerts. Also MPC acts in this role (doesn't exist in other time domain science areas).

TOM Toolkit Project

**Developing a general purpose software toolkit
for common target, observation & data management functions
with easy interfaces to user-written software.**

→ Enable astronomers to build TOM systems easily

→ Provide large set of core functions for commonly-used components

→ Provide well-defined interfaces to allow science-specific code to interact with the TOM

→ Being developed by LCO with community input

TOM Toolkit Design Philosophy

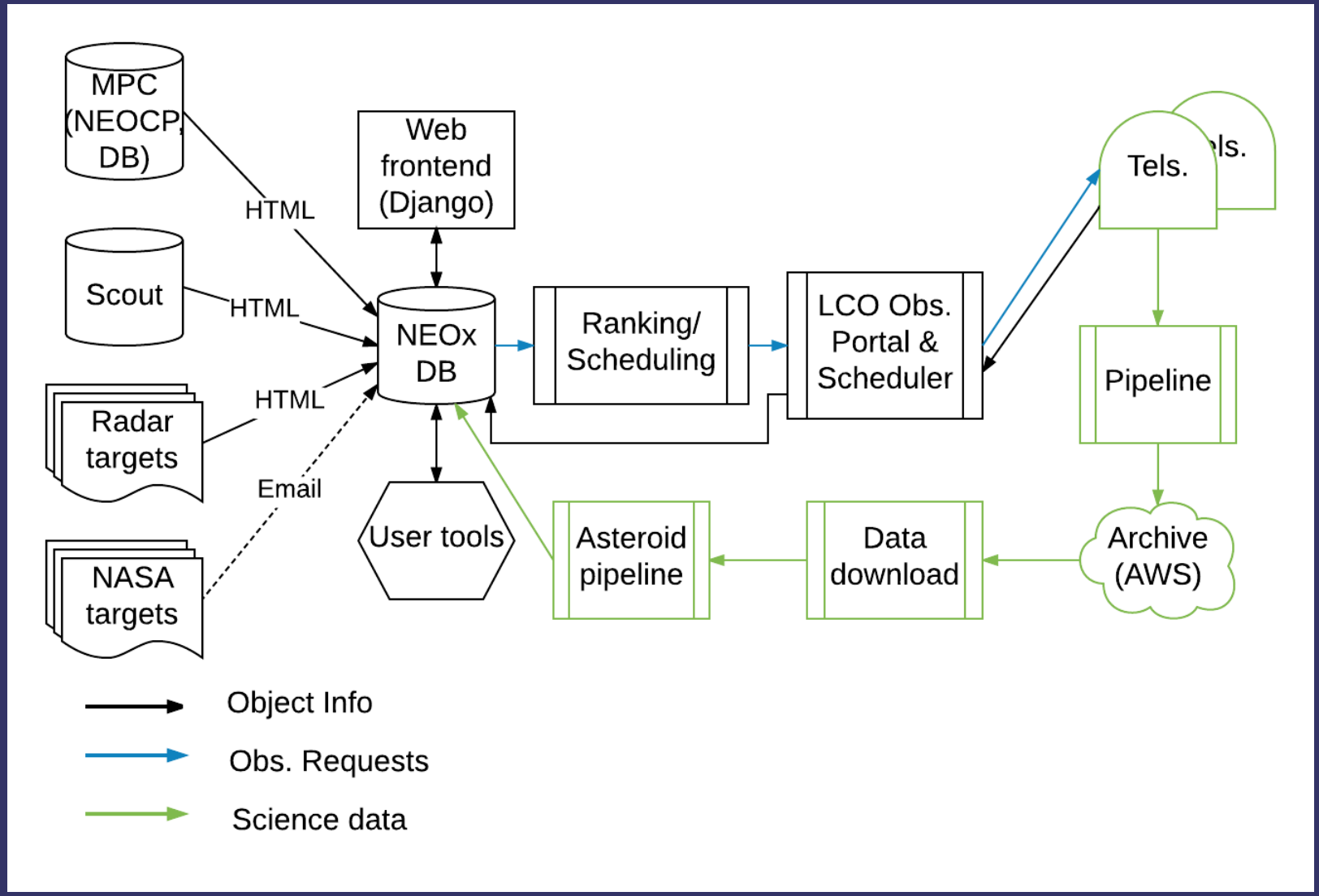
- Astronomers shouldn't need a software engineering degree to build or use a TOM
- One size doesn't fit all
  - Need to use the tools demanded by their project customize the system to their needs – which may evolve over time.
- Astronomers know how to do their science best
- TOMs encourage data share/collab. - but don't force it
- Toolkit itself built by professional software engineers

LCO's Solar System “TOM”

`NEOExchange`

https://lco.global/neoexchange/

Overview of NEOExchange



Observation and Follow-up Planning

- Balancing between 3 main types of follow-up:
  1) Short (20 – 40 min) follow-up of candidates (~2500/yr) within 1 – 24 hours
  2) Long (1 – 10+ hr) campaigns on radar targets (~100/yr) within 1 – 30 days
  3) Rapid response to close targets (~20+/yr) in <1 hour
- Figure of Merit calculation to produce target list
  - Use MPC metadata (arc length, last seen, score, *H*) and our computed ephemeris (V mag, dec.)
- Exposure and block length set by speed, V mag

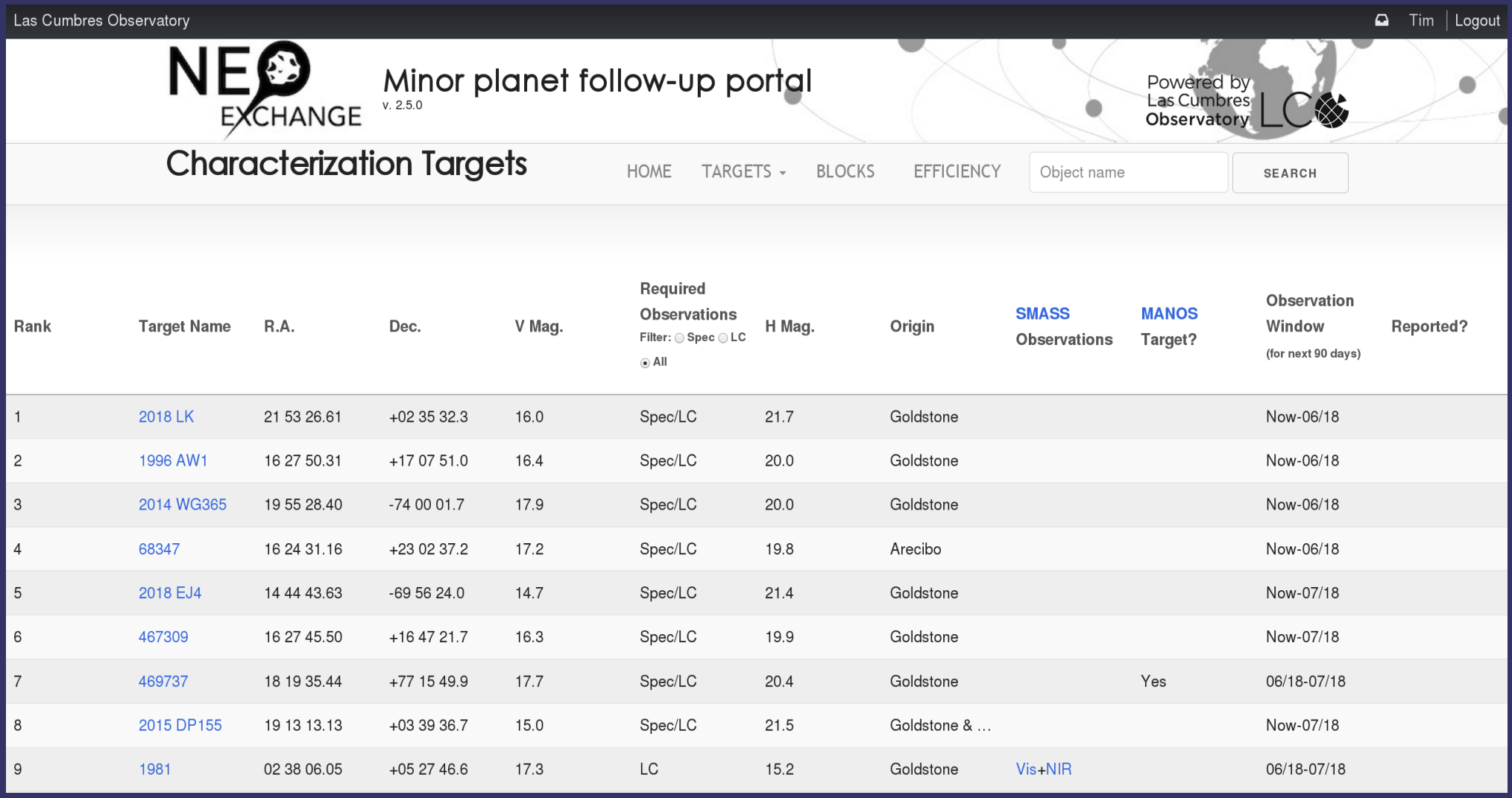
Extending NEOExchange: Photometry

- Bulk of NEOExchange has been for same “night” follow-up of NEO candidates and light curve blocks
- Now transitioned towards more follow-up and characterization work including Yarkovsky, Trojans
- Handles cadence obs. (repeat visits in a night, or across multiple nights)
  - Can take advantage of LCO's distributed sites for 24/7 monitoring
- Recently extended to handle multi-color observations
  - Can include ~simultaneous 2 – 3 observations using multiple LCO telescopes at a site

Extending NEOExchange: Spectroscopy

- Added spectroscopy support to NEOExchange:
  - Initially for LCO *FLOYDS* spectrographs
  - Ingesting and storing taxonomy and prior spectro. obs. info
  - Developed sky background calculator as function of solar activity, Moon, ecliptic and galactic latitude
  - Developed generalized SNR estimator based on telescope & instrument model
  - Can schedule spectro. obs (plus needed calibs) on the LCO network – testing underway, developing data reduction tools
- Developed longer term (weeks – months) planning tools for follow-up observations

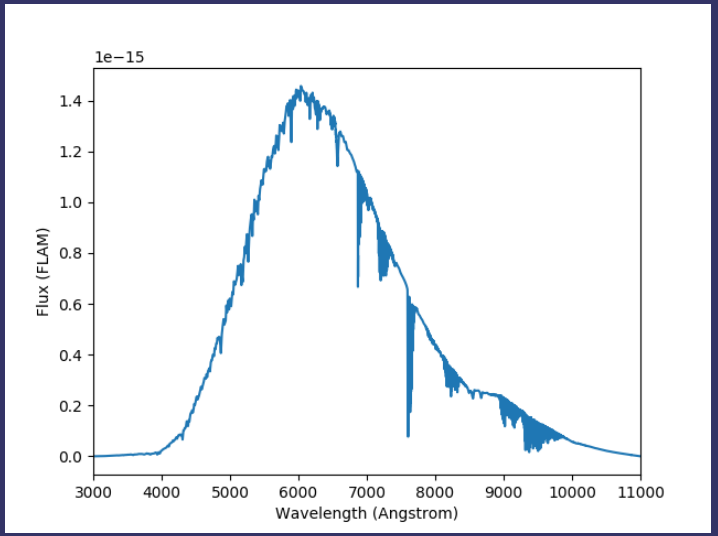
New characterization overview



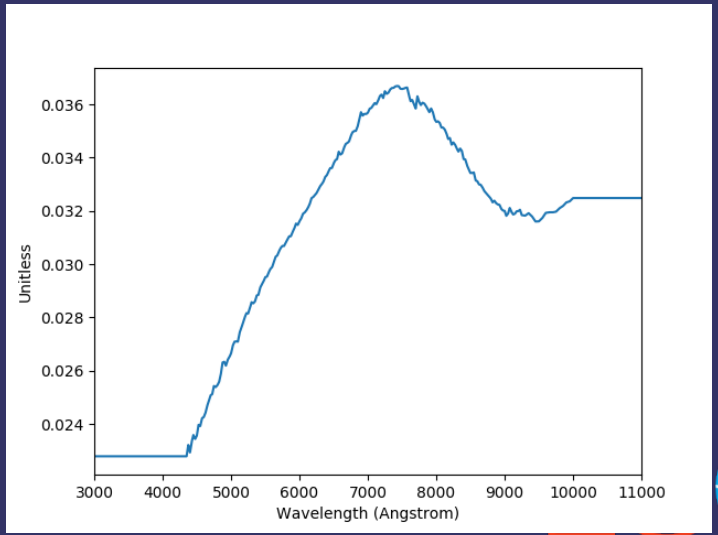
Rank	Target Name	R.A.	Dec.	V Mag.	Required Observations Filter: Spec LC All	H Mag.	Origin	SMASS Observations	MANOS Target?	Observation Window (for next 90 days)	Reported?
1	2018 LK	21 53 26.61	+02 35 32.3	16.0	Spec/LC	21.7	Goldstone			Now-06/18	
2	1996 AW1	16 27 50.31	+17 07 51.0	16.4	Spec/LC	20.0	Goldstone			Now-06/18	
3	2014 WG365	19 55 28.40	-74 00 01.7	17.9	Spec/LC	20.0	Goldstone			Now-06/18	
4	68347	16 24 31.16	+23 02 37.2	17.2	Spec/LC	19.8	Arecibo			Now-06/18	
5	2018 EJ4	14 44 43.63	-69 56 24.0	14.7	Spec/LC	21.4	Goldstone			Now-07/18	
6	467309	16 27 45.50	+16 47 21.7	16.3	Spec/LC	19.9	Goldstone			Now-07/18	
7	469737	18 19 35.44	+77 15 49.9	17.7	Spec/LC	20.4	Goldstone		Yes	06/18-07/18	
8	2015 DP155	19 13 13.13	+03 39 36.7	15.0	Spec/LC	21.5	Goldstone & …			Now-07/18	
9	1981	02 38 06.05	+05 27 46.6	17.3	LC	15.2	Goldstone	Vis+NIR		06/18-07/18	

Future Work for Characterization

- Validating sky and SNR models for spectroscopy
  - Develop a model for SOAR Goodman spectrograph
  - Extend model into NIR for Gemini/IRTF ?
- Extend and test characterization page to handle radar, NHATS, Yarkovsky target planning over days – months

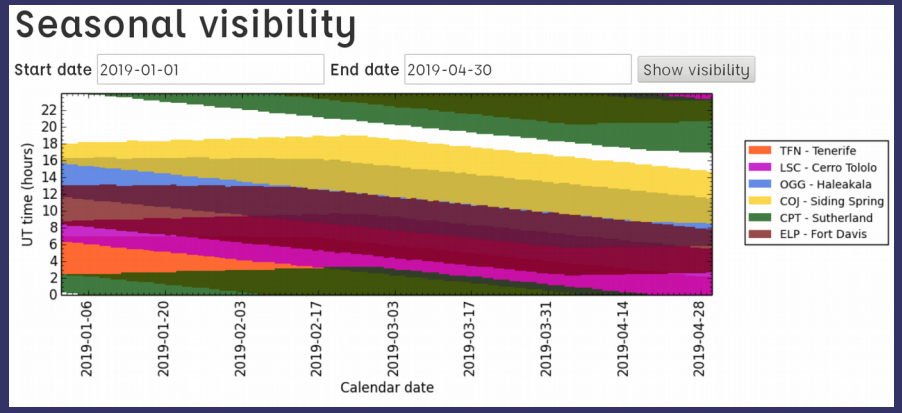


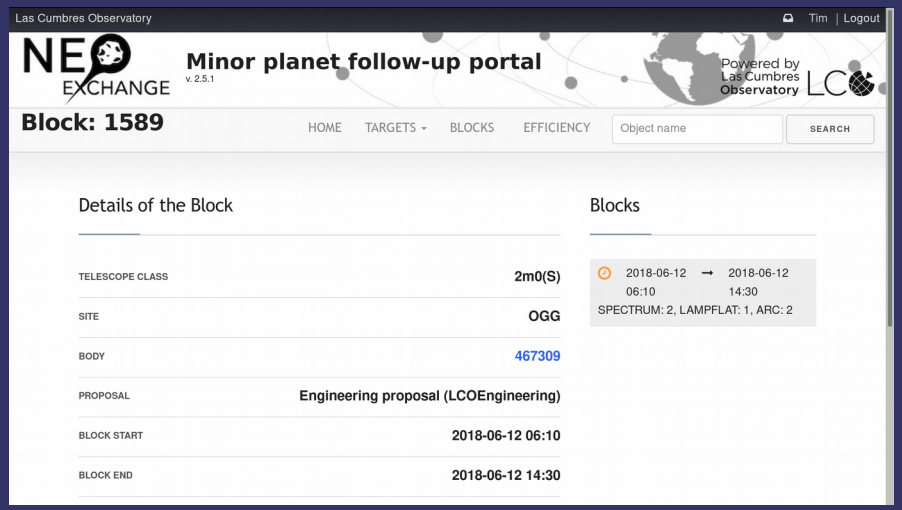
Synthesized observed Eros spectrum convolved with Earth atmosphere, telescope and instrument models



A TOM for Didymos Coordination ?

- LCO and NEOexchange have variety of tools to allow planning, scheduling, observation and data analysis for a multi-site/ telescope network
- Could extend and add tools to help out and coordinate Didymos characterization observations





What could a Didymos TOM help with?

- Some areas LCO and NEOexchange could help out with (and are building for other projects anyway):
  - Planning and visibility calculations for multiple telescopes around the world
  - SNR estimators for photometry and spectroscopy
  - Planning and visualization of planned/scheduled observations
  - Querying and feedback of observatory status
  - Report back of observations obtained

Other LCO Activities

- LCO is working with NOAO to roboticize SOAR & programmatically send requests from LCO scheduler for transient follow-up
  - Work scope docs being iterated; LCO have hired sw engineer
  - Gemini also interested
- Development of TOM Toolkit starting to pickup
  - Initial meeting of LCO astronomers and sw engineers to set scope
  - Have hired new software engineer (started early March)
  - Focusing on initial end-to-end, out of the box prototype: targets download, ingest & DB storage, schedule obs on LCO+1 other telescope, data retrieval

Extra Slides

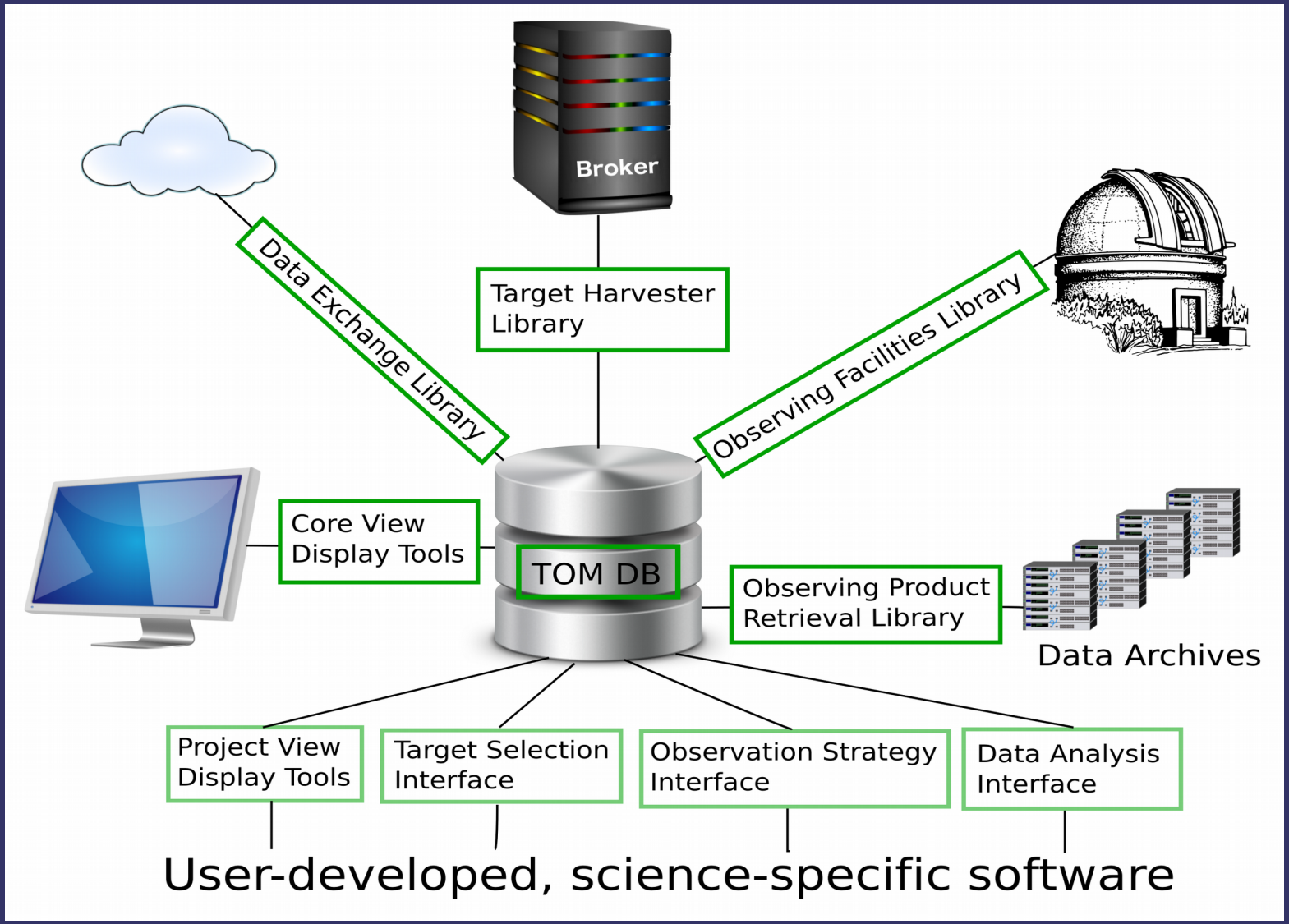
The TOM Toolkit Project

Tools for managing targets and observing programs

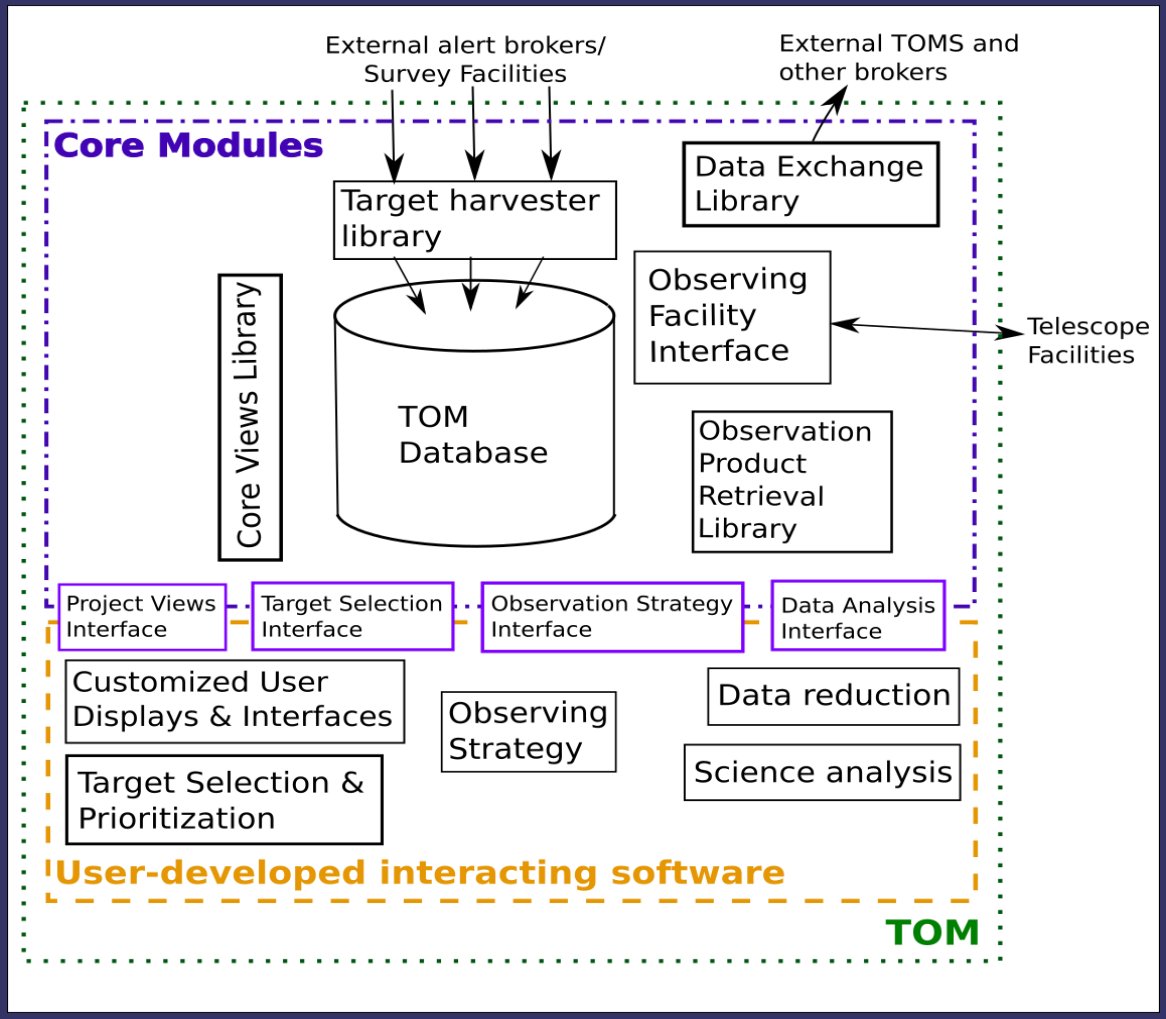
TOM Toolkit Project

- Developing a highly flexible toolkit for coordinating time domain observing programs in the 2020s
- Critical link in the discovery chain
- Designed to integrate with the Time-Domain Astronomy Network
- Alpha version expected ~mid 2019.

TOM Toolkit Components



Toolkit design allows flexibility



Modular software will consist of:

→ multiple libraries designed to perform common tasks

→ interfaces for interaction with user-developed software

Users will be able to pick and chose the functions they need

Scope of Project

Software development of core modules:

- Target Harvester Library
- Core Views Library
- Project Views Interface
- Observing Facility Interface
- Observation Product Retrieval Library
- Target Selection Interface
- Observation Strategy Interface
- Data Analysis Interface

Software development of example implementation

- A 'demo' TOM system

Documentation

- Full package description
- User tutorials

Community Engagement

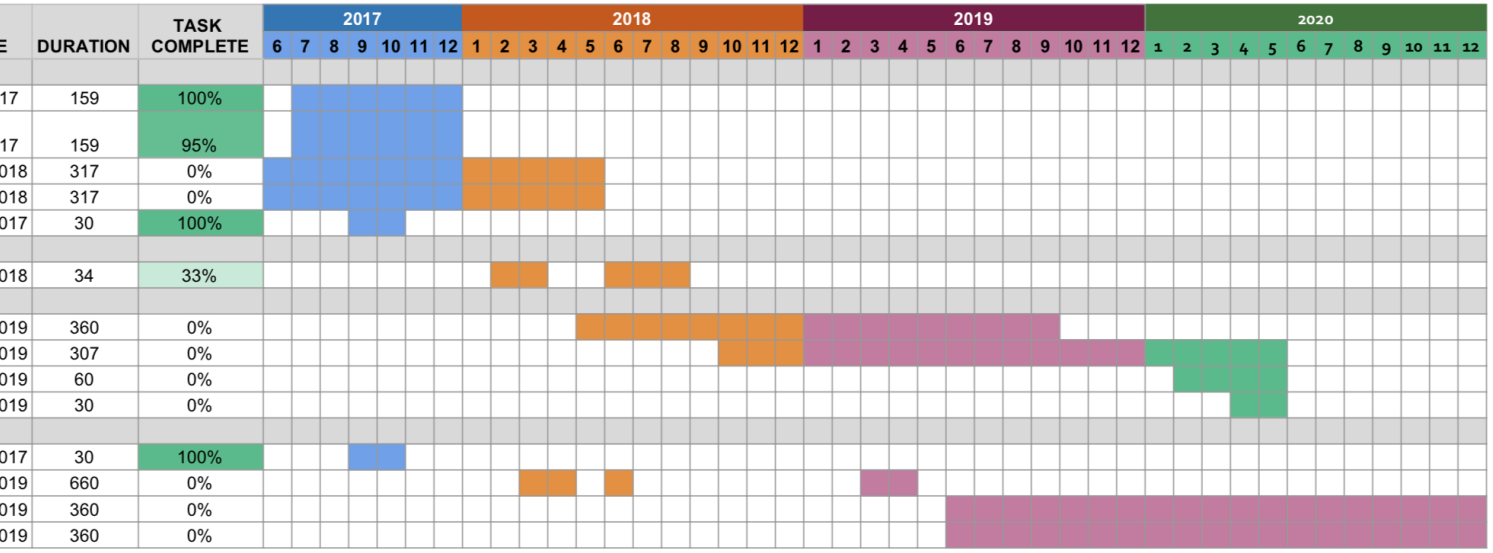
- Expert panel review
- Conference presentation
- Outreach to connected facilities
- Hands-on workshops
- Small grants competition

Timeline

TOM Toolkit Project Gantt Chart

PROJECT TITLE	TOM Toolkit Project	COMPANY NAME	Las Cumbres Observatory
PROJECT SCIENTIST	Rachel Street	DATE	2018 April 24
LEAD SOFTWARE ENGINEER	Mark Bowman	PRINCIPLE DEVELOPERS	Austin Ariba and David Collom

WBS NUMBER	TASK TITLE	START DATE	DUE DATE	DURATION	TASK COMPLETE
1	Project Definition and Planning				
1.1	Science Requirements	7/12/17	12/21/17	159	100%
1.2	Functional & Performance Requirements	7/12/17	12/21/17	159	95%
1.3	Resource estimates	6/15/201	5/2/2018	317	0%
1.4	Budget estimates	6/15/201	5/2/2018	317	0%
1.5	Design review	9/30/201	10/30/2017	30	100%
2	Recruitment				
2.1	Software hiring	2/1/2018	3/5/2018	34	33%
3	Software Development				
3.1	Core module development	5/8/2018	5/8/2019	360	0%
3.2	Documentation	7/1/2018	5/8/2019	307	0%
3.3	Demo TOM implementation	3/8/2019	5/8/2019	60	0%
3.4	Acceptance review	4/8/2019	5/8/2019	30	0%
4	Community Engagement				
4.1	Recruit expert review panel	9/30/201	10/30/2017	30	100%
4.2	Conference presentations	3/1/2018	12/31/2019	660	0%
4.3	Training workshops	1/1/2019	12/31/2019	360	0%
4.4	Developer grants program	1/1/2019	12/31/2019	360	0%



Scientific, Functional & Performance Requirements - complete
Core module development underway, June 2018
Minimum Viable Product expected ~June 2019
Project completion ~June 2020

Community engagement will ramp up summer 2019

Time-Domain Astronomy Network

Goal is to make it possible to seamlessly request observations from multiple facilities

Make 'workhorse' instruments available with time-domain friendly scheduling

Phase 1: develop infrastructure to robotically submit observation requests to SOAR/Goodman spectrograph through the LCO scheduler

[Described by J. Elias in Time Domain and Transient Surveys, 10704-13]

Phase 2: robotically submit observation requests to Gemini telescopes

Future: interface with other facilities

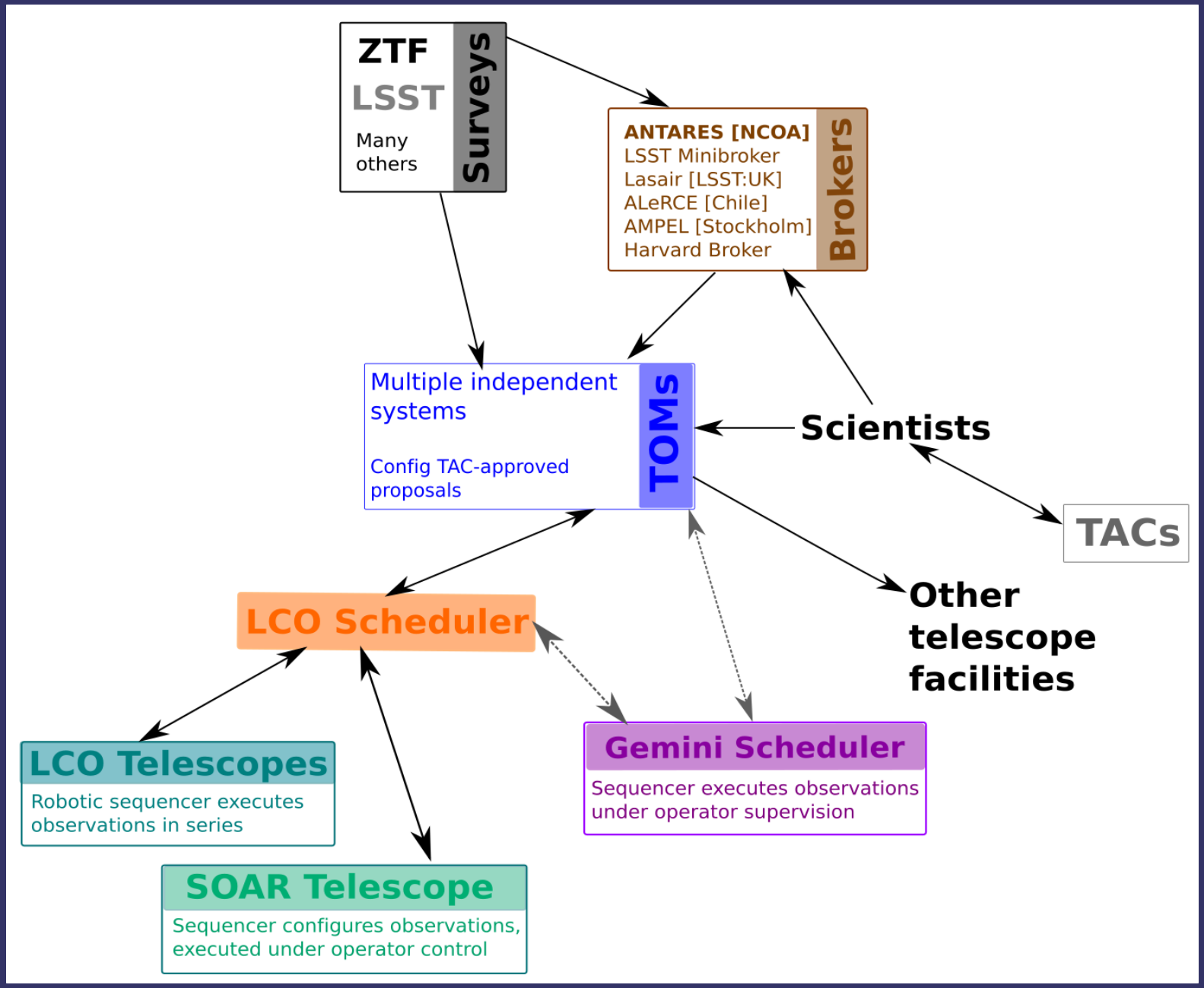
NOAO

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

SOAR TELESCOPE

LCO

Time-Domain Astronomy Network



NOAO

SOAR TELESCOPE

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