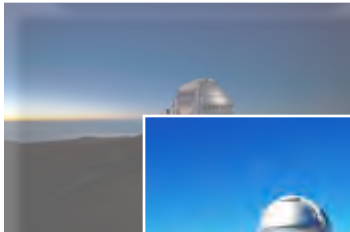
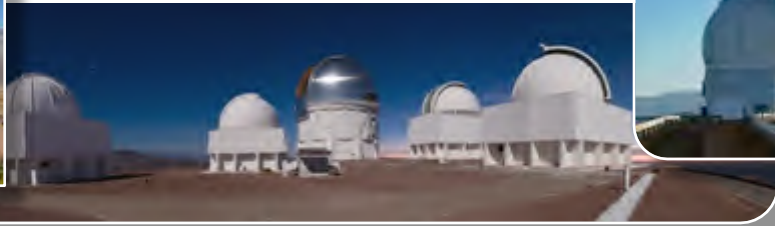


A System for LSST Follow UP

Robert Blum, NOAO



LSST Follow Up System

The Team

- Andy Adamson (Gemini)
- John Blakeslee (Gemini)
- Bob Blum (NOAO)
- Adam Bolton (NOAO)
- Todd Boroson (LCO)
- Cesar Briceño (NOAO/SOAR)
- Mark Bowman (LCO)
- Jay Elias (SOAR)
- Steve Heathcote (NOAO)
- Bryan Miller (Gemini)
- Steve Ridgway (NOAO)
- Eric Saunders (LCO)
- Rachel Street (LCO)
- Joanna Thomas-Osip (Gemini)
- Nikolaus Volgenau (LCO)

LSST Follow Up System

The Goal

- Deliver an end to end Follow up System for Community use
- Support LSST Science
- Support follow up science before LSST (e.g. ZTF public stream)
- Think of this as a project to deliver a capability for the OIR system

LSST Follow Up System

The Story So Far

- LSST is NSF focus of the next decade on the ground
- AURA NSF funded centers seek to maximize science impact of facilities by providing capabilities to broad user community
- NOAO mission evolving rapidly around large surveys, coherent data sets, tools to exploit data sets
- NOAO has strong and accomplished history of supporting time domain science, follow up observing
- LSST event stream and annual data releases make for a golden opportunity (indeed stated need) for AURA facilities to be key elements in the LSST era

OIR System Optimization

Need: Comprehensive Follow Up System

- Elmegreen and Najita-Willman reports, Follow Up System: [key element of OIR System Optimization](#)
- End to End system capable of delivering science data products given merit based review, allocation of resources, brokering of alert streams, complex science based target and observation management ([TOM](#)), resource deployment, pipeline and data distribution.
- Build on AURA facilities with key partnerships is the best way to stand up a (phased) system.
- Preliminary development of system NOAO/SOAR, Gemini ([see Adamson talk](#)), Las Cumbres Observatory (LCO; [see Boroson talk](#))

Follow Up System

What is in Hand and What Needs Doing

- Broadly, **in good shape with telescopes and instruments** to start: SOAR, Gemini, Blanco, LCO. All noted in Kavli report
- Gemini has new broad wavelength coverage spectrograph (OCTOCAM) coming. GMOS (N+S)/F2/GNIRS in mean time.
- SOAR has Goodman and (soon) TS4.
- Blanco has DECam for non-LSST cadence, other filters
- NOAO developing ANTARES to broker LSST event stream (**goal is to broker ZTF public stream, Spring 2018**)
- **Need development** at interface of ANTARES and science based target and observation management (TOM) and interface between target management and network of resources (telescopes+instruments and a dynamic scheduler).
- **Need further** (spectroscopic) pipeline/tool development

Follow Up System Development Path

- Favor a plan (and project) that starts with
 - limited observing nodes
 - limited observing modes
 - delivers capability in a phased way in next ~ two years
 - is modular and extensible to new non-Federal partners
 - provides full capability by LSST start of survey 2023
- In parallel, NOAO is working to deploy ANTARES in the near term to support other public surveys/alert streams like ZTF. Expect to broker ZTF public stream spring 2018 (come talk to us at NOAO booth)

- Three blocks
 - 1) Broker (ANTARES)
 - 2) Target and Observation Management (TOM)
 - 3) Network (includes the magic of the scheduler and all control agents at the telescope level)
 - For LCO network is robotic, redundant, homogenous nodes
 - AURA will add unique, non robotic, but automated nodes

Follow Up System Development Path

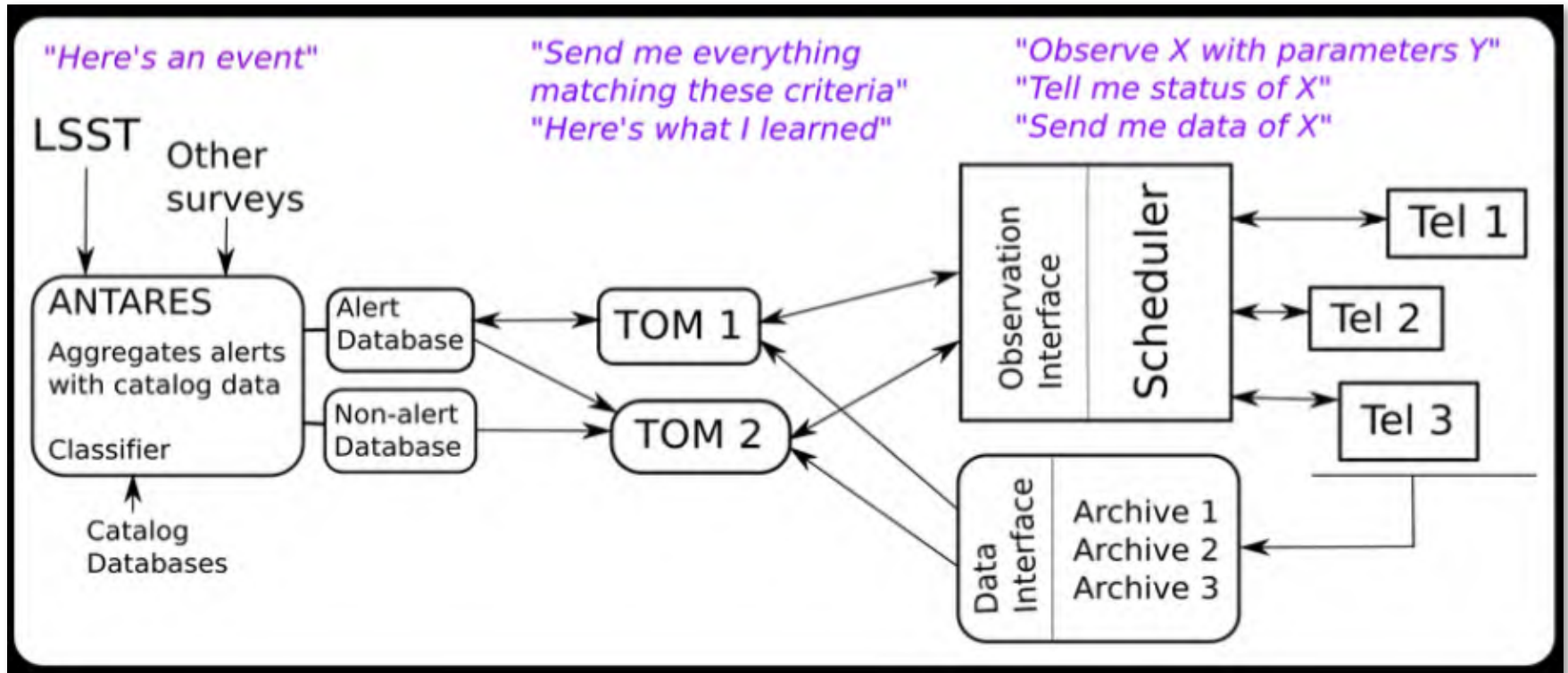


Image credit Rachel Street, LCO

Follow Up Project I

Phased Implementation

- Phased deployment: AURA/LCO first. Phases overlap
- Phase 1
 - Connect LCO scheduler to SOAR
 - Key goal: operate SOAR with dynamic schedule for one night
 - In parallel ANTARES running on real event streams
 - SOAR automation development starts and continues here
 - SOAR data reduction, archive ingest, archive user access
 - Engage with Gemini for requirements in their new OCS.
- Complete by end FY18

Follow Up Project II

Proposed Phased Implementation

- Phase 2 minimal requirements for TOM functionality for phase 2.
 - Submit user described observations to LCO and SOAR
 - TOM can access pipeline data from web service
 - ANTARES in operation (with public stream from ZTF; a minimum demonstration of ZTF->ANTARES will be in hand at this point)
 - Open access to users (before LSST) with minimum prototype capability
 - TOM can interact with both LCO and SOAR observations
 - Scheduler drives automated observations on SOAR.
 - Minimal end-to-end system V1.0 (ZTF-ANTARES-TOM-LCO/SOAR) by end **FY19**
 - Add Gemini (proof of concept activity like SOAR in phase 1)

Follow Up Project II

Proposed Phased Implementation

- Phase 2b
 - Scheduler drives sequence of “time-domain only” observations on Gemini
- Phase 2c (“goal”)
 - Scheduler incorporates Gemini static queue into Gemini observing schedule
 - Reduced Gemini data available to users
 - Open access to users (before LSST)

Follow Up Project III

Proposed Phased Implementation

- Phase 3
 - All AURA and LCO facilities integrated
 - Hooks in place to accept other facilities
 - End to end system operating and supporting users for ZTF
 - Real-time data reduction for quality assessment, basic characterization
- Phase 4
 - Support community science with LSST commissioning and operation

Follow Up Project III

what's happening now

- Working with Gemini, SOAR, LCO on “preliminary design”
- Organize and develop the scope of work for phase 1+2 (2018), assign work packages for development
- Resource estimates
- Allocate supplemental resources to fund project
 - Integrated with aspects of base programs as appropriate
 - leverage expertise of all partners
- LCO leading community based TOM development
- SOAR working on automation, data pipelines, interfaces
- Gemini developing new OCS

Follow Up Project Issues, opportunities

- Instrument upgrades in longer term
- SOAR and Blanco need “Q” observing support (possibly could be handled by OA’s if modes are restricted)
- Common libraries for spectroscopic reduction
- Socializing community to need to redirect telescope resources to dedicated dynamically scheduled modes

End of Presentation System Under Construction!



Image credit LSST/AURA

Follow Up Project

Backup slides

OIR System Optimization

Maximizing science return in the era of LSST

- NSF guidance to NOAO in March 2016, in response to recommendations of Elmegreen et al. 2015
- Five categories of activity:
 - I. Telescope time exchange & data access across the OIR system
 - II. Planning new capabilities
 - III. Event broker development, archives, and data-product serving
 - IV. LSST follow-up coordination
 - V. Community preparation for the LSST era
- Further input from Kavli-funded May 2016 workshop
- Initial NOAO response to NSF in May 2016
- Follow Up System is only a part of this response ([see talk by Norman, this meeting](#))

End to End Follow Up

Pre-concept

NOAO LSST Followup Project			
LSST Followup Elements	NOAO Program	Partner	OIR Deliverable
Community Training	CSDC	LSSTC	V
Proposal Preparation	TAC/CSDC	Gemini	I, V
Proposal Review	TAC	Gemini	I
Allocation	TAC		I
Brokering	ANTARES	UA CIS	
Target selection	CSDC	LCO(GTN)	II, III
Dynamic Scheduling	NOAO ETS	LCO(GTN)	II, III, IV
Data Taking	Blanco, SOAR	Gemini, SOAR, LCO	II
Data transport	DMO		II
Data Reduction	CSDC, DL	Gemini, SOAR, LCO	II, III
Data distribution	DMO		III, IV
TDS tools	TDS, DL		II, IV, V
Archive/data product serving	DMO, DL		I, III, V

- Cross-matches with available catalogs
- Characterizes based on properties like color, light curve, variability, etc.
- Estimates rarity
- Applies filters to select a particular kind of object



<https://www.noao.edu/ANTARES/>

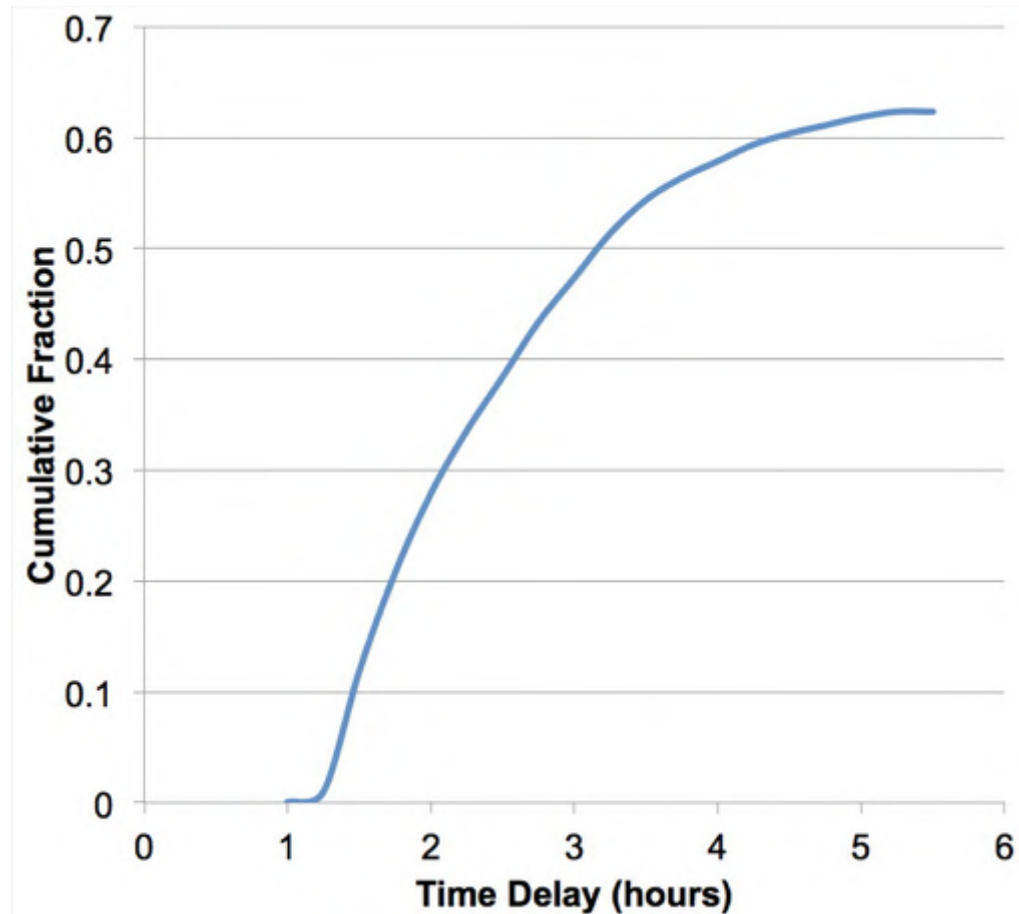
- TOMs make up the main science layer:
- Collect and further filters targets from alert streams (e.g. brokers)
- Are aware of resources available to the team(s)
- Request observations
- Collect and display the returned data
- Manage data access for members

Several are in use by SNe, exoplanet, NEO, AGN, and microlensing teams by LCO and collaborators.

LSST Follow Up from Gemini North

Fraction of LSST sky available from Hawaii with airmass < 2.0

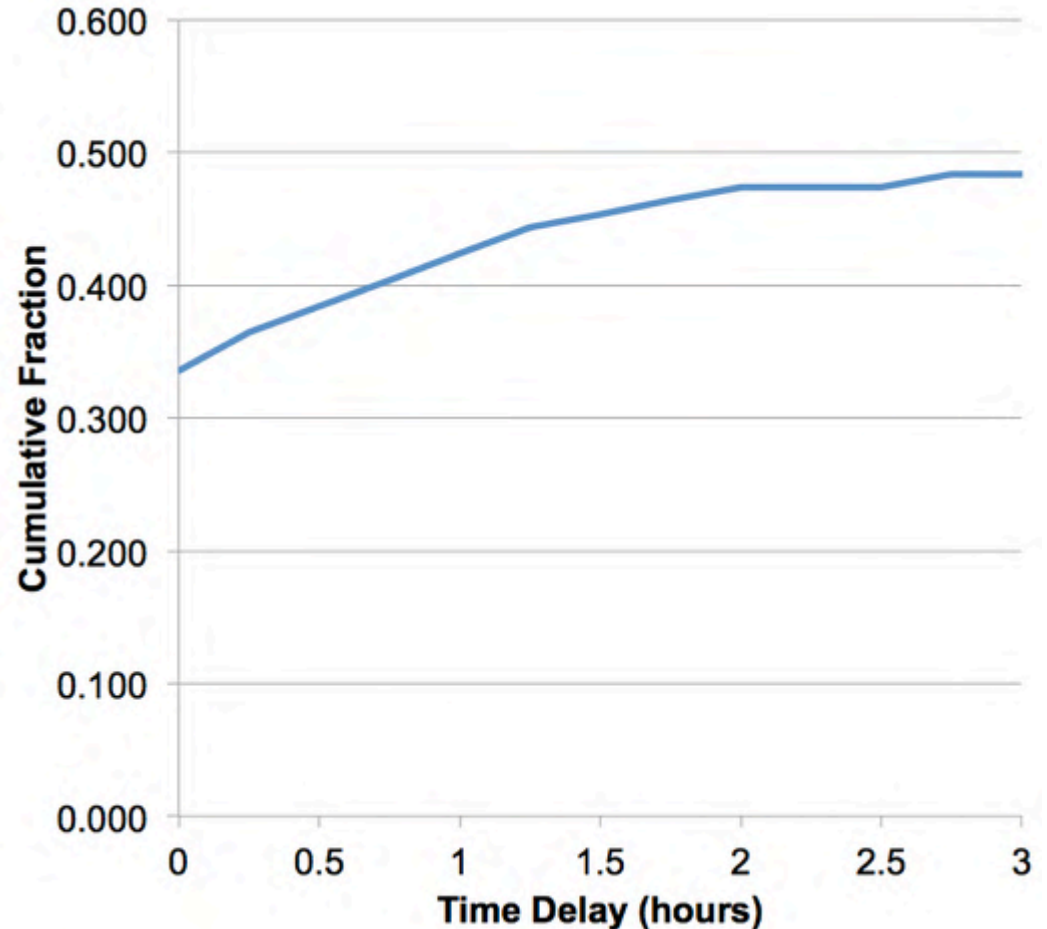
- 50% of LSST sky available within 3 hours
- Allows time for Broker processing and triage
- Most LSST observing near HA=0, allowing several hours access by Chile facilities
- Ref: Time-domain infrastructure discussion at <https://www.noao.edu/meetings/lsst-tds/>



LSST Follow Up from Kitt Peak

Fraction of LSST sky available from KPNO with airmass < 2.0

- Referred to LSST sky at transit
- 35% available to Kitt Peak contemporaneously



Follow Up Project I

Phased Implementation

- Phased deployment: AURA/LCO first. Phases overlap
- Phase 1
 - Connect LCO scheduler to SOAR
 - Key goal: operate SOAR with dynamic schedule for one night
- Phase 1 Details
 - Parallel work on TOM's
 - In parallel ANTARES running on real event streams
 - Define what a good schedule looks like
 - Define schedule criteria (TAC grade; position, exp time, mode, time window, maximum airmass, cadence, lunar distance, ...)
 - Step 1: execute a schedule (manually)
 - Step 2: react with dynamic input to schedule

Follow Up Project I

Proposed Phased Implementation

- More Phase 1 Details
 - Define what information is returned
 - Raw data to NOAO Science Archive with API
 - SOAR automation development starts and continues here
 - SOAR data reduction, archive ingest, archive user access
 - Engage with Gemini for requirements in their new OCS.
Definition of what needs to be in scheduler by end Q2 FY18
 - Understand how moving objects are going to be handled (specify format/protocol for moving object trajectory) Handle this in obs definition. Add to initial schedule for experiment.
- Complete by end FY18

Follow Up Project II

Proposed Phased Implementation

- Phase 2 minimal requirements for TOM functionality for phase 2.
 - Configure filters and receive targets from ANTARES
 - User describes observation
 - Submit user described observations to LCO and SOAR
 - TOM can access pipeline data from web service
 - ANTARES in operation (with public stream from ZTF; a minimum demonstration of ZTF->ANTARES will be in hand at this point)
 - Specific filters available?
 - What does service look like? Network TOMs or feed info back to ANTARES centrally?)
 - Open access to users (before LSST) with minimum prototype capability

Follow Up Project II

Proposed Phased Implementation

- Phase 2a project development
 - TOM can interact with both LCO and SOAR observations
 - Scheduler drives automated observations on SOAR.
 - Reduced SOAR data available to users; data archive access.
 - Feedback about resource status. Capabilities so that schedule side knows what is happening/available. TOM will allow users to query status.
 - Real time observation status, did it succeed? Does it need to be re-observed and why.
 - Minimal end-to-end system V1.0 (ZTF-ANTARES-TOM-LCO/SOAR) by end **FY19**
 - Add Gemini (proof of concept activity like SOAR in phase 1)

Follow Up Project II

Proposed Phased Implementation

- Phase 2b
 - Scheduler drives sequence of “time-domain only” observations on Gemini
 - Resolve differences in scheduling strategy
- Phase 2c (“goal”)
 - Scheduler incorporates Gemini static queue into Gemini observing schedule
 - Fully reduced Gemini data available to users
 - Open access to users (before LSST)