

Time Domain Alerts from LSST & ZTF

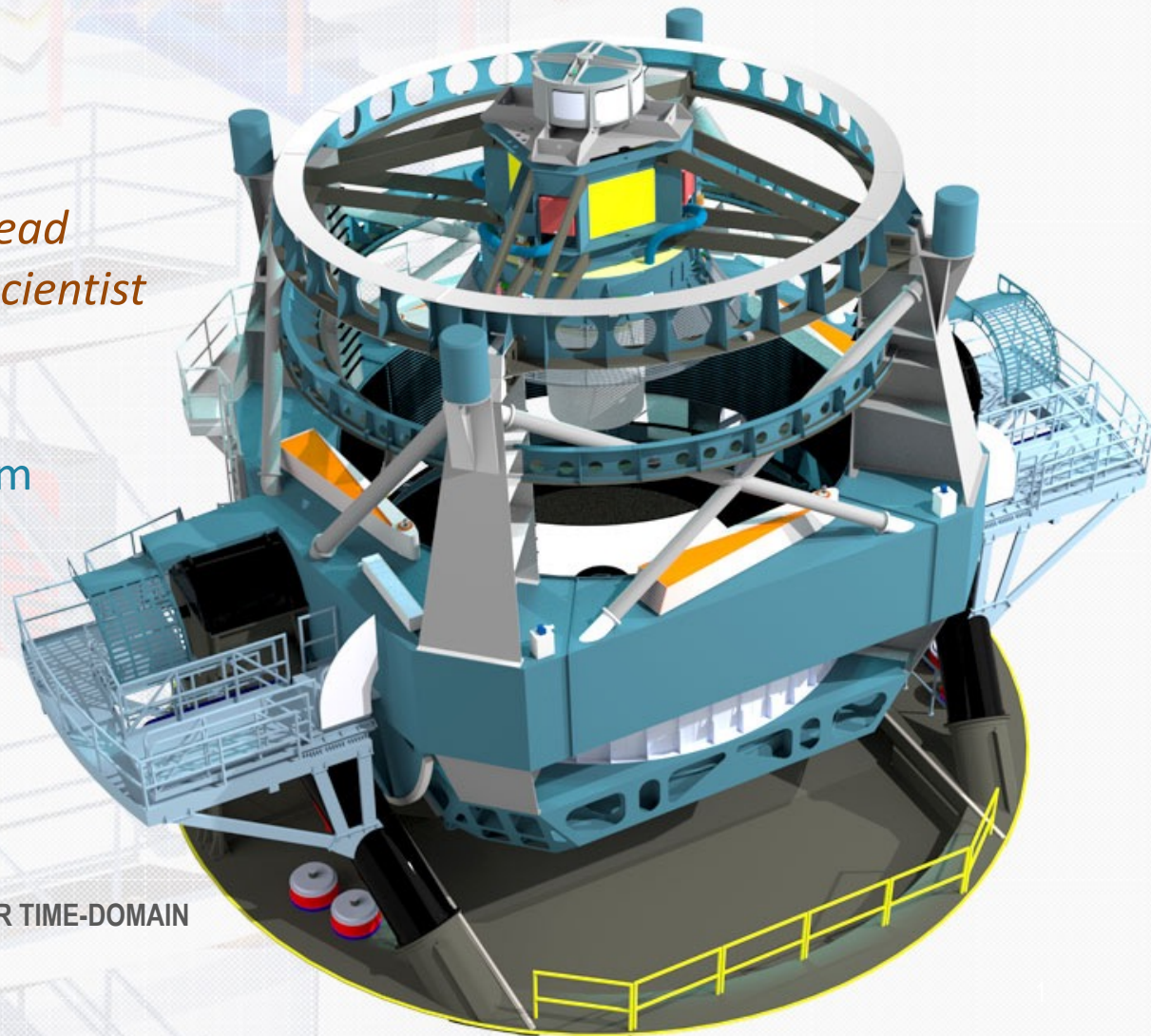
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and the ZTF Collaboration



BUILDING THE INFRASTRUCTURE FOR TIME-DOMAIN
ALERT SCIENCE IN THE LSST ERA

May 22, 2017

Today I'll provide an overview of ZTF & LSST's planned alert streams.



Brief overview & comparison of the key survey parameters

Discussion of alert packet contents from a science & broker point of view

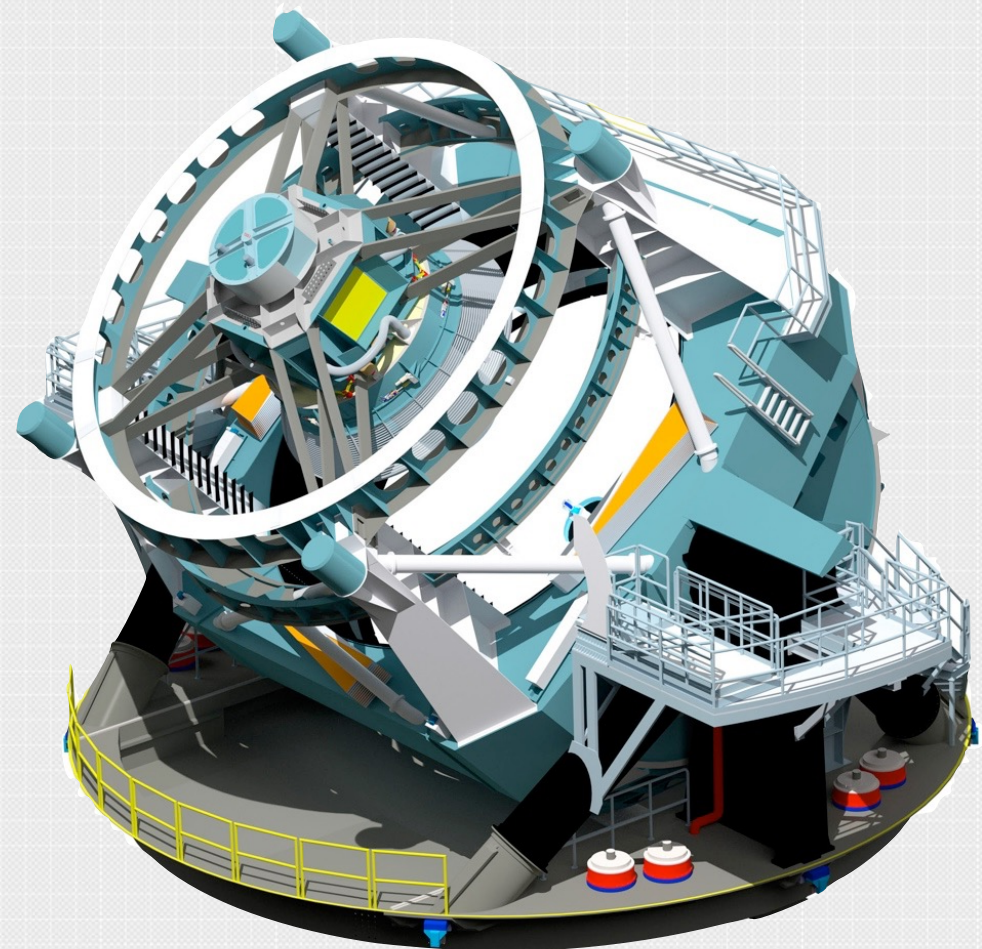
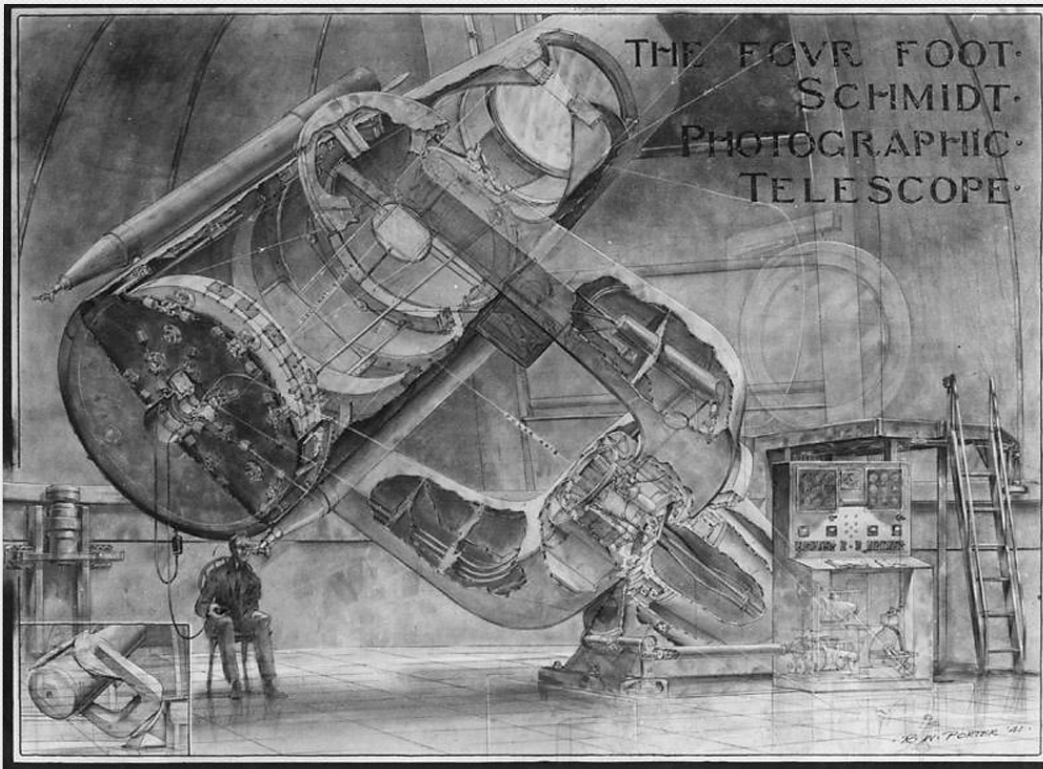
Planned architecture for alert distribution and pre-filtering

Pointers to documentation—though much is under active development

Expected timelines

[Next talk: M. Patterson will describe potential formats & implementation.]

ZTF & LSST are quite different...



ZTF & LSST are quite different...



	ZTF	LSST
Effective Aperture	1.2 m	6.7 m
Field of View	47 deg ²	9.6 deg ²
Median Image Quality	2.0"	0.7"
Filters	g, r (i)	u, g, r, i, z, y
Single exposure magnitude range (r)	13.5-20.5	16-24.7
Areal survey speed	3760 deg ² hr ⁻¹	840 deg ² hr ⁻¹
Average yearly observations per field	290	82
Survey dates	2018-2020	2022-2032

...but ZTF's alert stream is a useful prototype for LSST's.



	ZTF	LSST
Number of detections	1 trillion	7 trillion
Number of objects	1 billion	37 billion
Nightly alert rate	1 million	10 million
Nightly data rate	1.4 TB	15 TB
Alert latency	< 20 minutes	60 seconds

“Brokering” is an overloaded term.

May help this week to be specific about what functionality we mean:

- distribution of alert packets
- filtering of alerts
- cross-correlation with other catalogs or alert streams
- classification
- provision of user interfaces
- community coordination
- triggering & followup
- storage and archiving
- annotation & citation
- manage “discovery”
- ...probably more?

LSST is planning a ten-year survey.

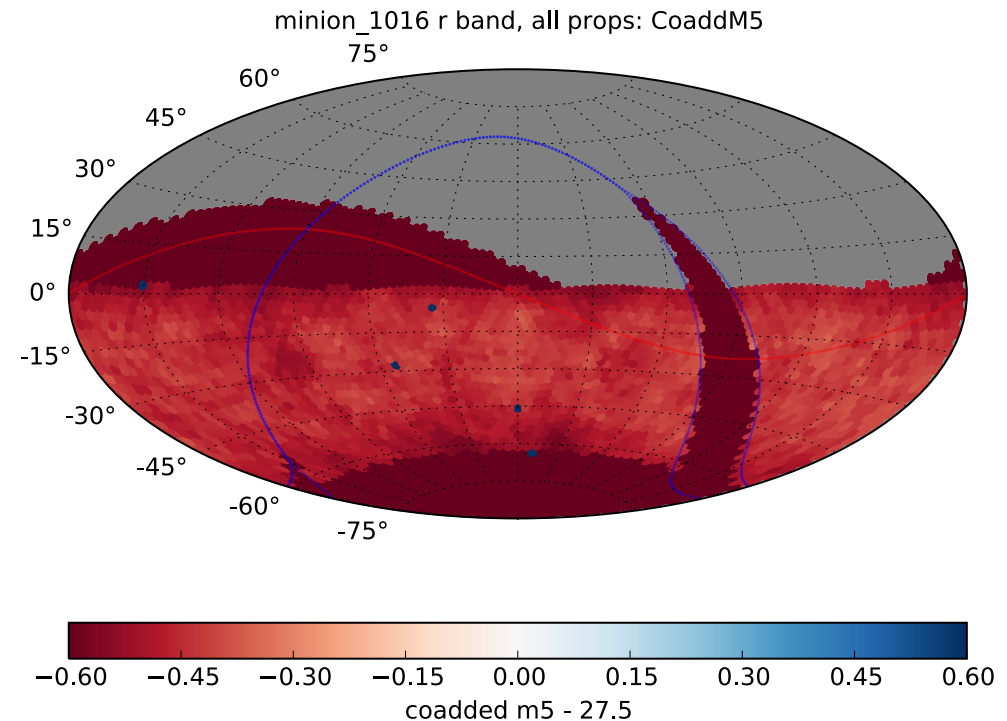


Survey in ugrizy bands, with
~825 visits per pointing

Wide-Fast-Deep:
2x/night every three nights
over 18,000 square degrees

Special programs:

- Deep Drilling
- Galactic Plane
- North Ecliptic Spur
- South Celestial Pole



Ongoing cadence development & evaluation:
[https://github.com/
LSSTScienceCollaborations/
ObservingStrategy](https://github.com/LSSTScienceCollaborations/ObservingStrategy)

ZTF will perform two public surveys over three years.



Will use 50% of the collaboration time to survey the visible Northern Sky at all Galactic latitudes

Two visits/night (g+r) for asteroid rejection \Rightarrow 3-day average cadence

Similar to LSST Wide-Fast-Deep

systematic samples of supernovae, SLSNe, TDE, AGN, variable stars...

Nightly sweep of the Galactic Plane ($|b| < 7^\circ$; nightly g+r)

rare and exotic variables and binaries, CVs and novae, M-dwarf flares, large-scale gyrochronology, young star outbursts, and more

Initial MSIP surveys will be revised after ~ 18 months.

ZTF promised an “LSST-like” alert stream for its public surveys.



World-public in near real time

Provide all alerts from image differencing regardless of likely event type
(explosive transient vs. variable star vs. asteroid)

Rich alert packets

Full streams to a finite number of community brokers

Use LSST-relevant formats and infrastructure where possible

Goal:

seed community development of time-domain resources ahead of LSST

MSIP proposal called for (photometric) alerts starting in the second year;
we have accelerated alert release into the first year.

A series of software pipelines produces the LSST alert stream.

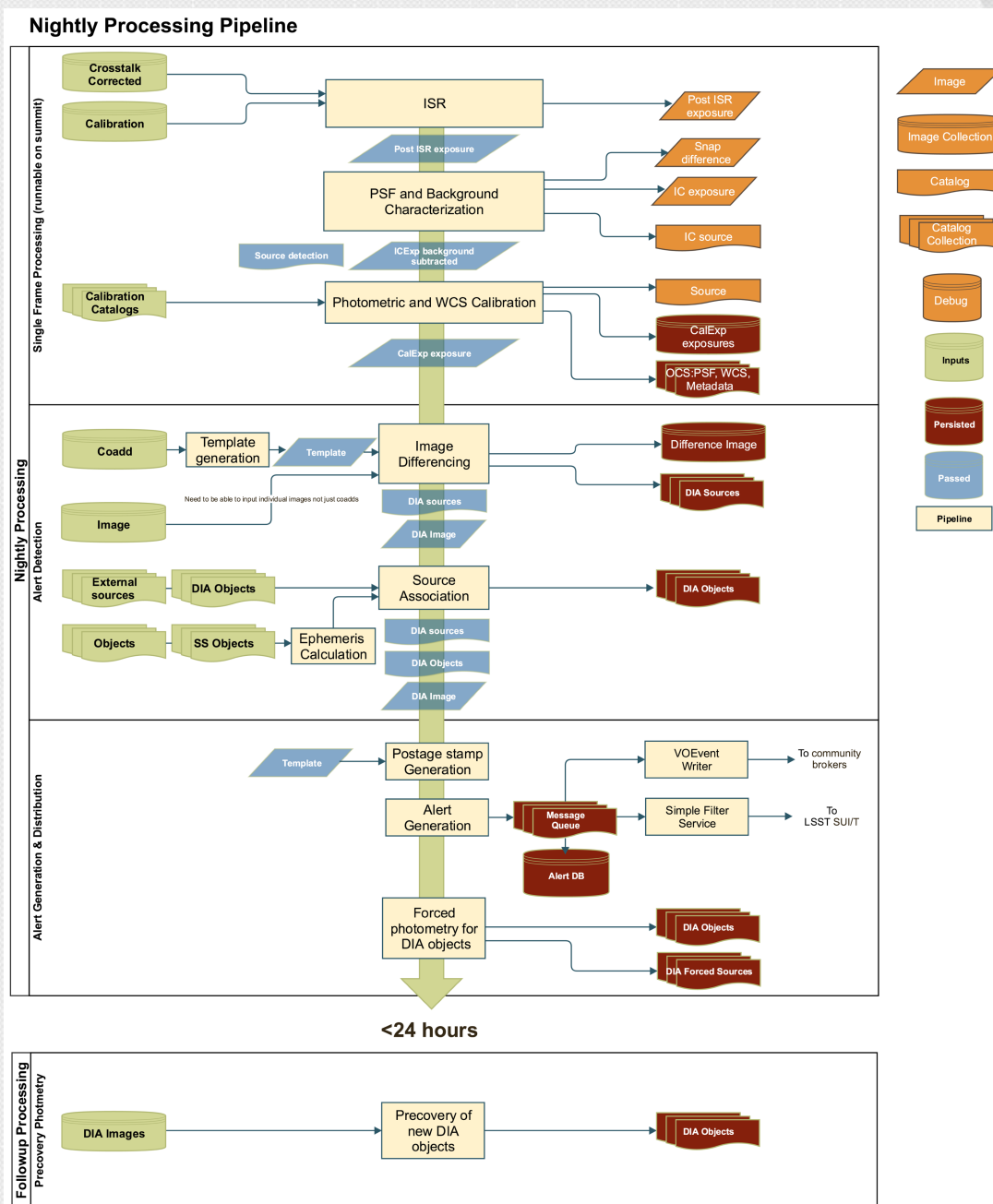


Single Frame Processing

Alert Generation

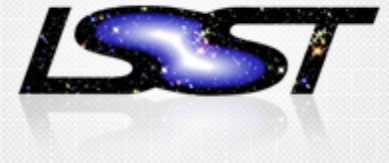
Alert Distribution

Forced Processing

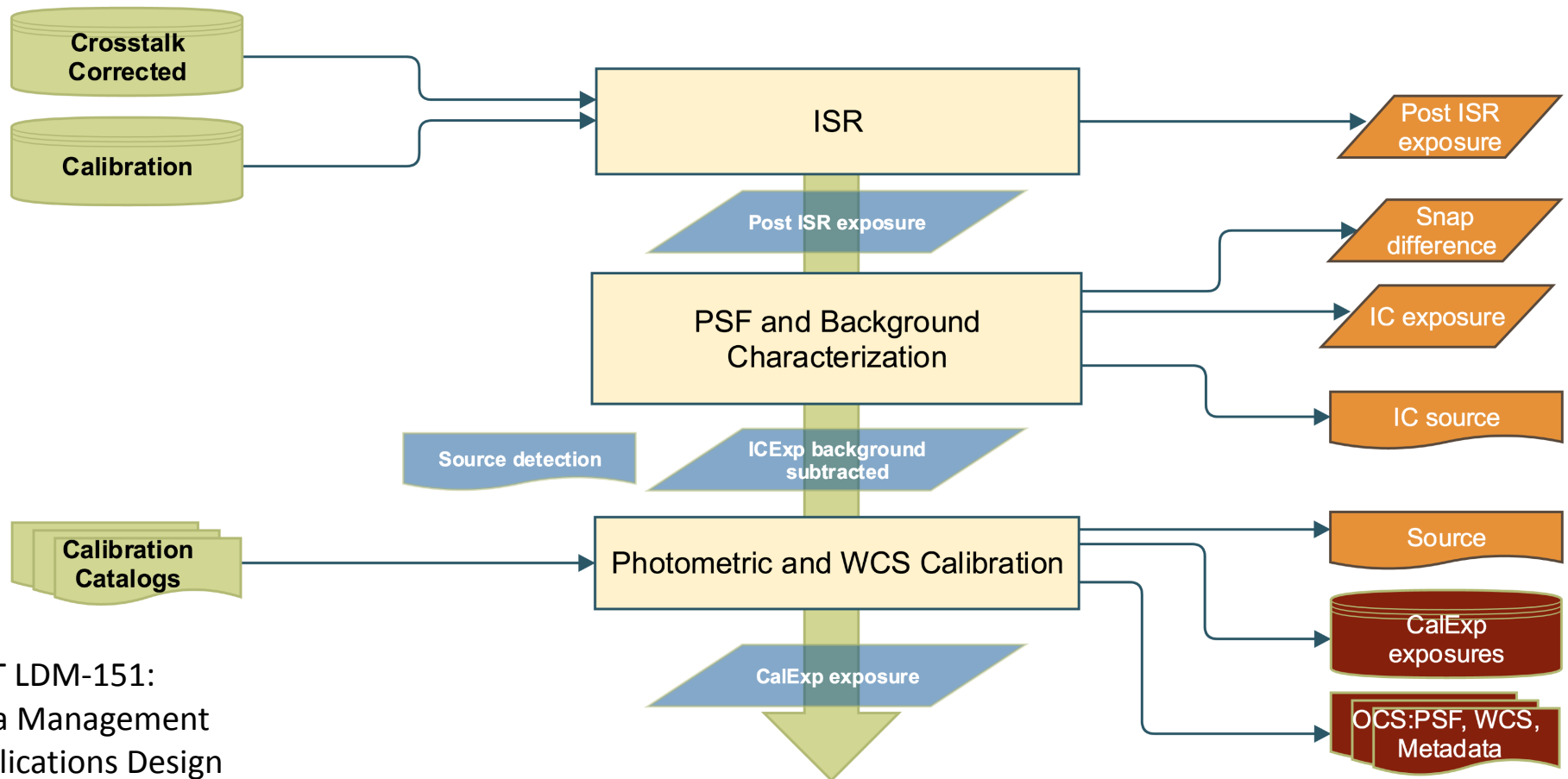


LSST LDM-151:
Data Management
Applications Design

ls.st/LDM-151



Single Frame Processing



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Image Generation

```
graph TD; Coadd[(Coadd)] --> TemplateGen[Template generation]; Image[(Image)] --> TemplateGen; TemplateGen --> Template[/Template/]; Template --> ImageDiff[Image Differencing]; ImageDiff --> DIA_Sources1[DIA sources]; ImageDiff --> DIA_Image1[/DIA Image/]; ImageDiff --> DiffImage[(Difference Image)]; ImageDiff --> DIA_Sources2[DIA Sources]; ExternalSources[External sources] --> DIA_Objects1[DIA Objects]; Objects[Objects] --> SS_Objects[SS Objects]; SS_Objects --> EphemerisCalc[Ephemeris Calculation]; EphemerisCalc --> SourceAssoc[Source Association]; DIA_Objects1 --> SourceAssoc; SourceAssoc --> DIA_Sources3[DIA sources]; SourceAssoc --> DIA_Objects2[DIA Objects]; SourceAssoc --> DIA_Image2[/DIA Image/]; SourceAssoc --> DIA_Objects3[DIA Objects];
```

Need to be able to input individual images not just coadds

LSST LDM-151:
Data Management
Applications Design

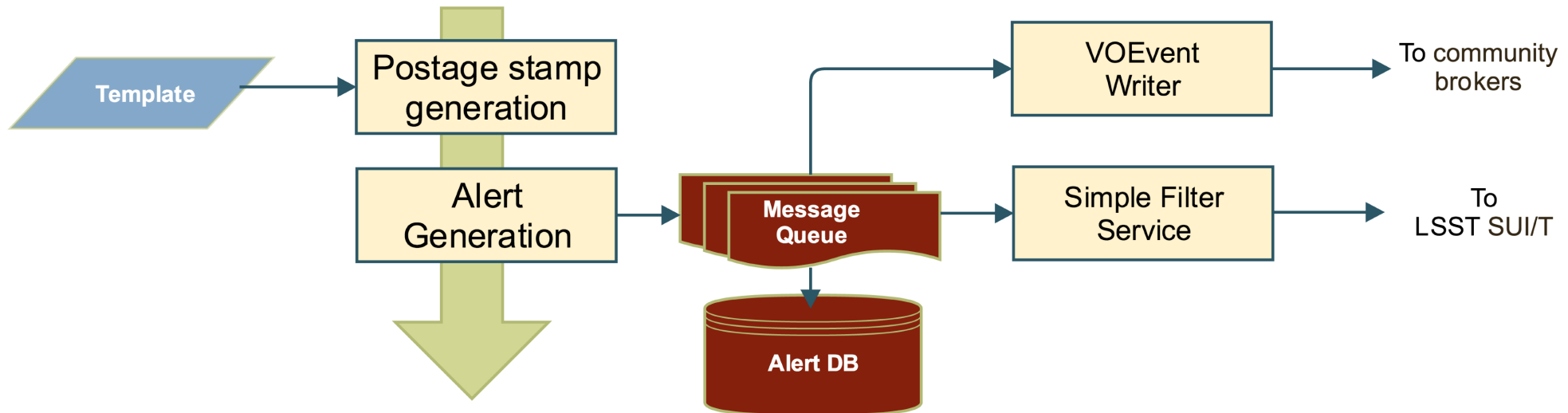
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ls.st/LDM-151

Alert Distribution packages and sends alerts.



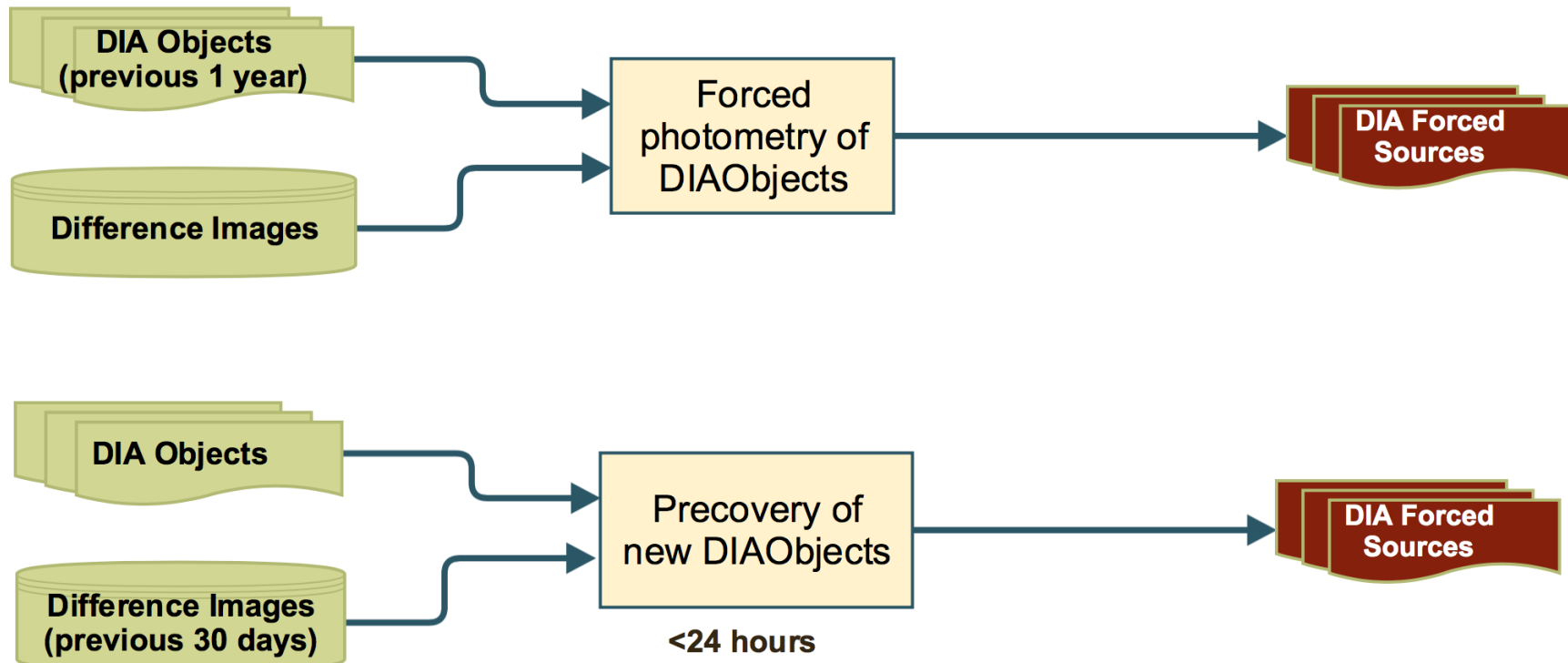
Alert Distribution



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Applications Design

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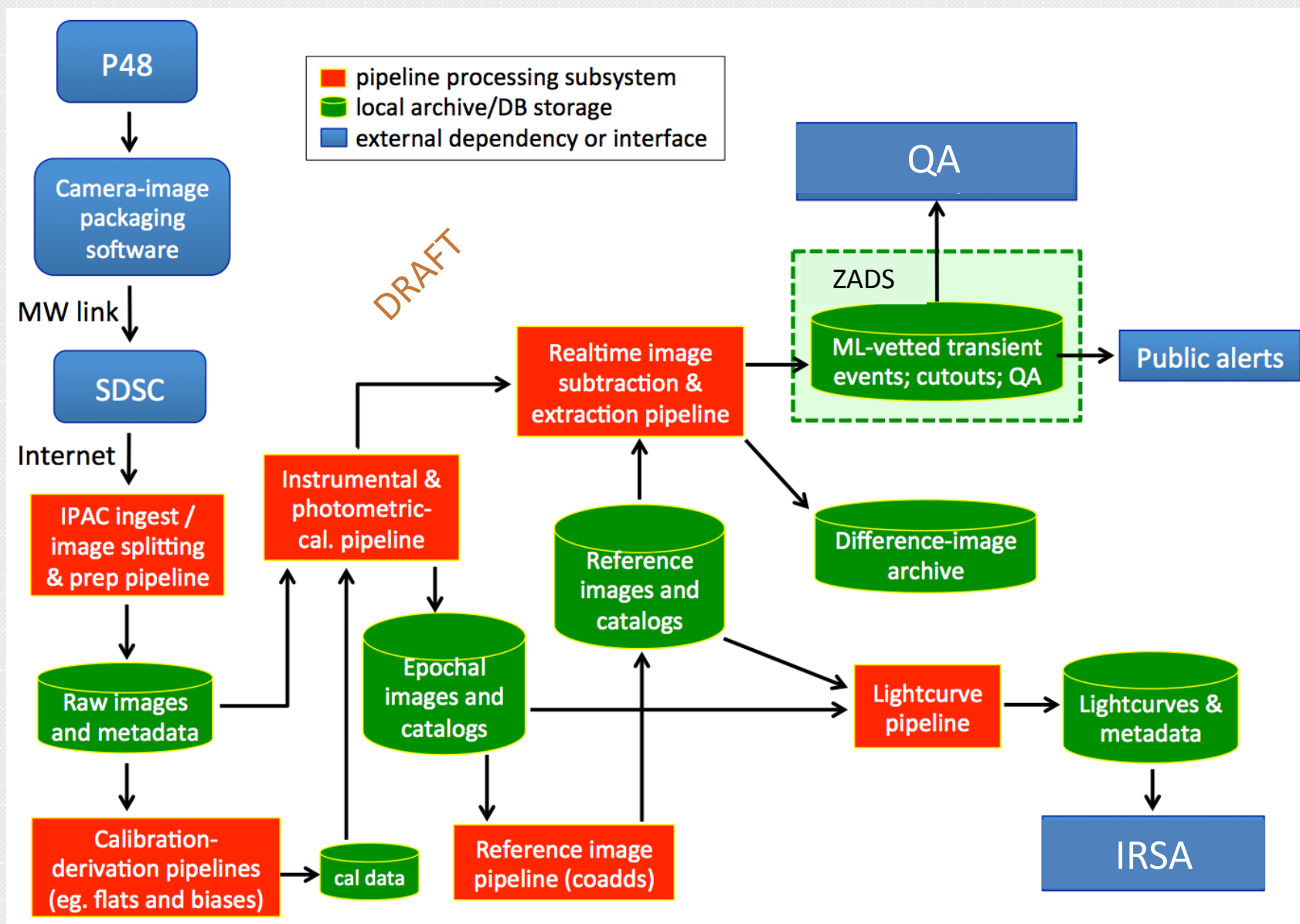
Recovery and Forced Photometry



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Data Management
Applications Design

ls.st/LDM-151

ZTF processing is conceptually similar to LSST's, but has no forced processing.



LSST uses rich alert packets to minimize followup queries.



Each alert (a `VOEvent` packet) will at least include the following:

- *alertID*: An ID uniquely identifying this alert. It can also be used to execute a query against the Level 1 database as it existed when this alert was issued
- *Level 1 database ID*
- Science Data:
 - The `DIASource` record that triggered the alert
 - The entire `DIAObject` (or `SSObject`) record
 - All previous `DIASource` records -> last 12 months
 - A matching `DIAObject` from the latest Data Release, if it exists, and its `DIASource` records
- Cut-out of the difference image centered on the `DIASource` (10 bytes/pixel, FITS MEF)
- Cut-out of the template image centered on the `DIASource` (10 bytes/pixel, FITS MEF)

LSST LSE-163:
Data Products
Definition Document

[ls.st/DPDD](https://lsst.st/DPDD)

DIASource and DIAObject records contain a wide range of measurements.



DIASources:

- Position
- aperture/PSF/dipole/trailed fluxes
- moments
- likelihoods, extendedness, spuriousness

DIAObjects:

- linkages to DIASources [-> light curve], L2 Objects
- time series statistics

SSObjects:

- linkages to DIASources
- variety of solar system parameters

LSST LSE-163:
Data Products
Definition Document

[ls.st/DPDD](https://lsst.st/DPDD)

ZTF packets contain a different set of features.



Candidate records:

- shape measurements
- association with known asteroids
- Real/Bogus score
- **crossmatches** to a small set of catalogs
(TBD; likely PanSTARRS, local universe, star/galaxy catalog)

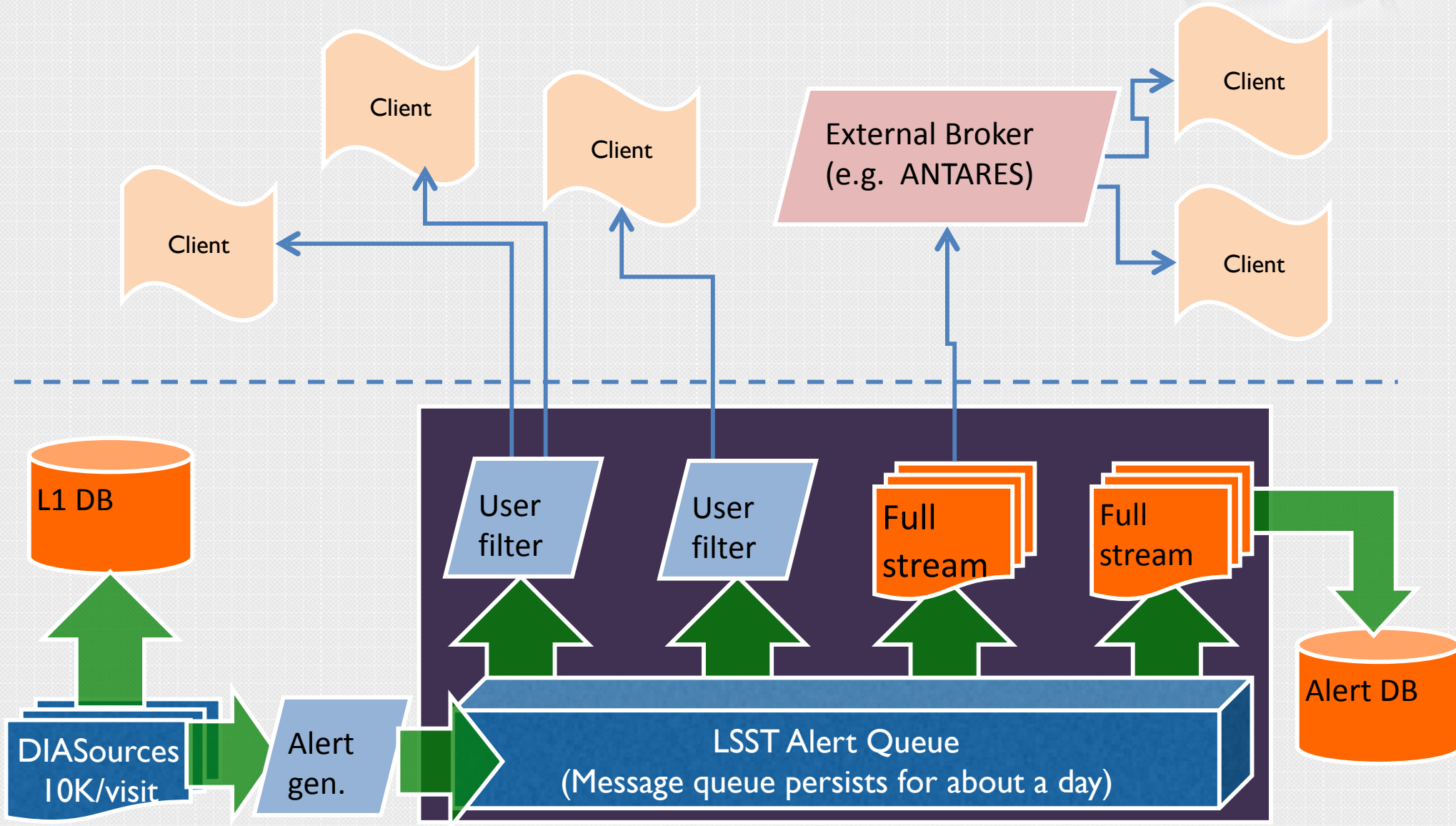
cutouts

30 days of *cone-search* history (including upper limits)

- no precomputed timeseries features

documentation in progress

LSST alert distribution requires a new community ecosystem.



At ~20 full sized events per visit per user (or summarizing the lightcurve for all events in ~40 numbers) we can serve ~500 simultaneous users for the cost of a single full data stream

LSST will provide a “mini-broker” service



User-defined filters that act *only* on alert packet contents

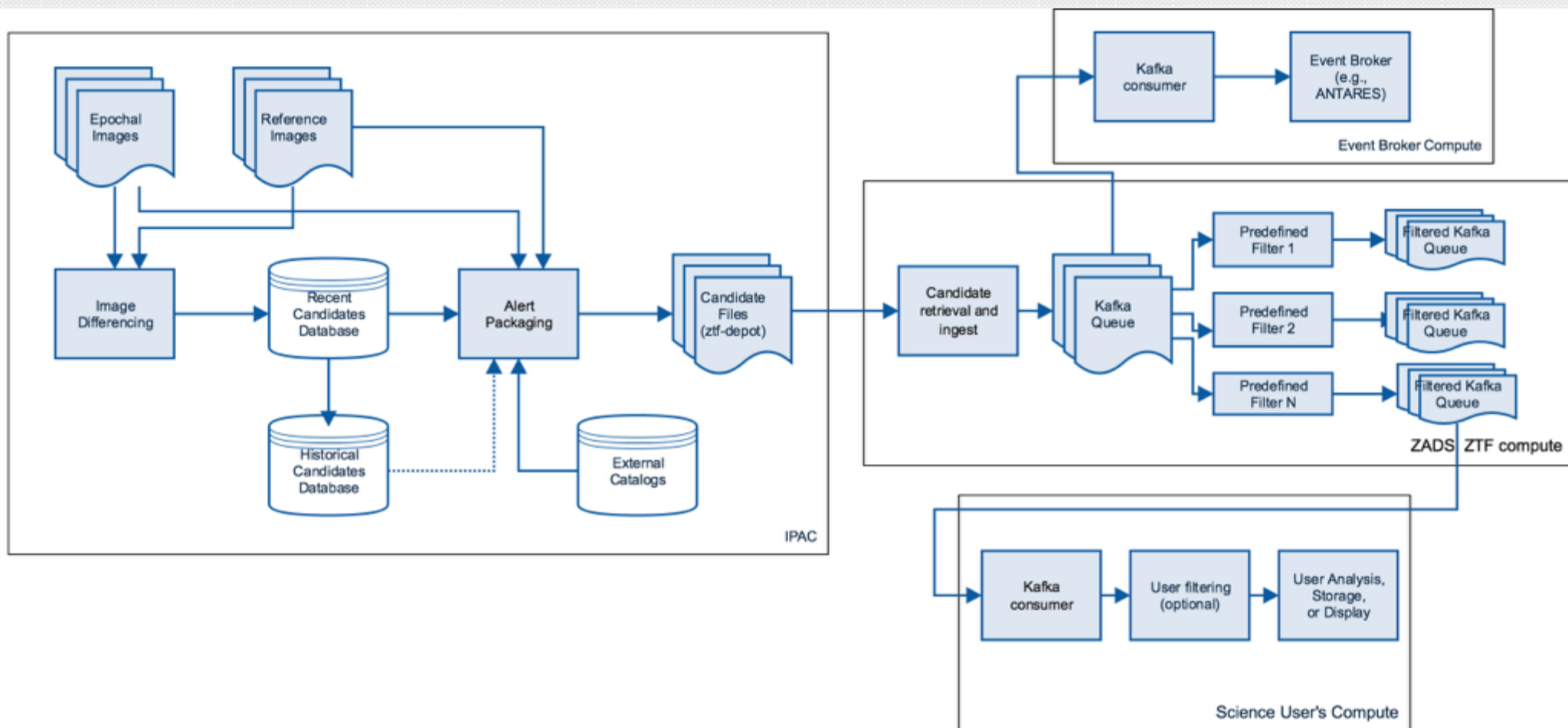
Access to the filtered stream through LSST’s Science User Interface & Tools

Cap of ~20 alerts per user per visit; some limits on computing capacity

LSST LSE-163:
Data Products
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[ls.st/DPDD](https://lsst.org/DPDD)

ZTF will replicate the LSST alert distribution architecture.



ZTF will replicate the LSST alert distribution architecture.



Alert Generation
(IPAC)

IPAC

Community
Brokers

“ZADS”
ZTF Alert Distribution
System

ZADS ZTF compute

User Access to
Pre-filtered
Streams

Different brokers will have different capabilities.



Action	ZADS filtering	LSST mini-broker	Community Brokers
Filter single alert packets on their contents	✓	✓	✓
Accept user-defined filters	✗	✓	?
Crossmatch to external catalogs	✓	✗	✓
Crossmatch to external alert streams	?	✗	✓
Classify events	?	✗	✓

ZTF provides a near-term opportunity to prototype time-domain brokers on an LSST-like alert stream.

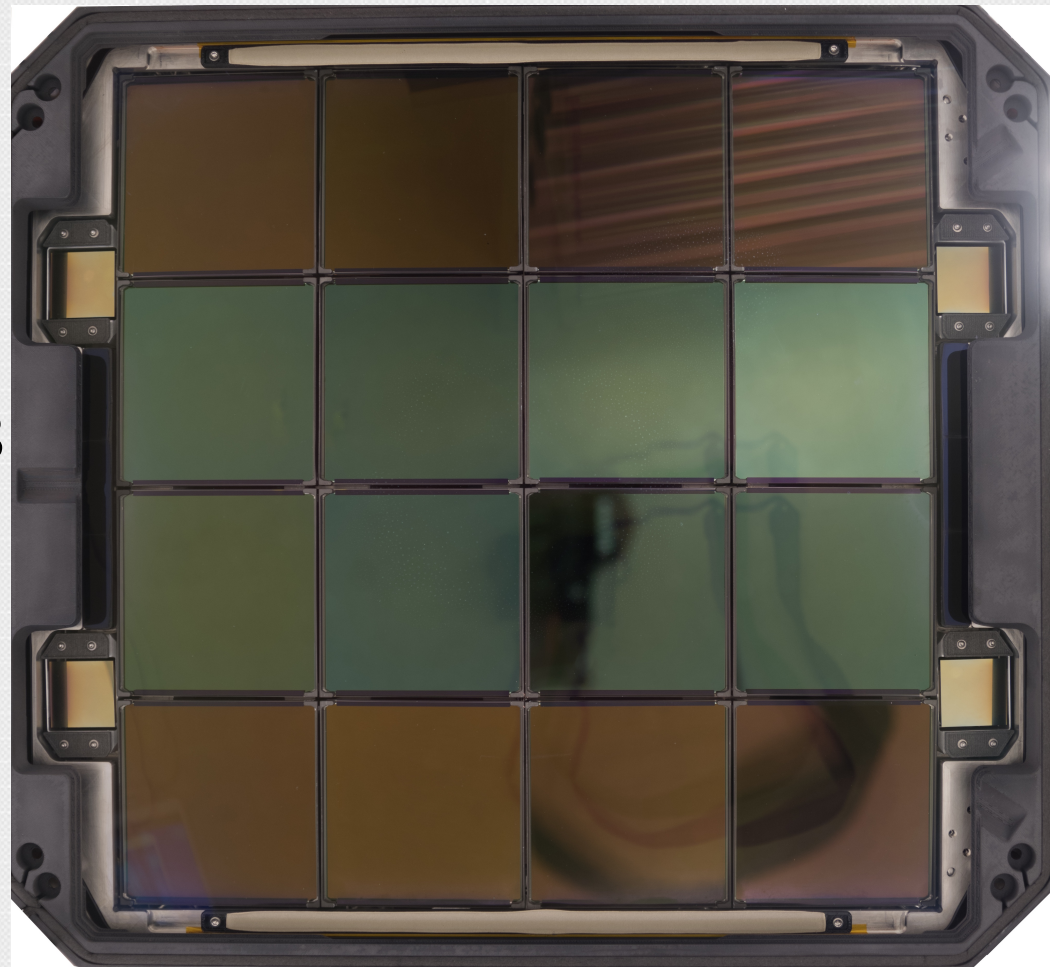


First light expected this August

Survey begins ~Jan. 2018

Aiming for public alerts by Q2 2018

(Limited by ZADS construction, template building, false-positive control.)



Conclusions



Exploiting LSST's time-domain capabilities requires development of a community system of software brokers

ZTF will use prototype versions of LSST tools to provide an LSST-like alert stream and filtering service beginning next year

Many technical decisions and scientific questions remain—your feedback and ideas are welcome!