Low-latency LIGO-Virgo Alerts

Reed Essick
on behalf of the LVC

4th AMON Workshop
December 4, 2015

LIGO low-latency alerts

Why low-latency?

What does LIGO mean by “low-latency”?

What challenges are associated with low-latency?

LIGO low-latency alerts

Why low-latency?

-Directed follow-up and multi-messenger astronomy

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LIGO low-latency alerts

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What challenges are associated with low-latency?

- non-stationary, non-Gaussian noise background (“glitches”)
- wide parameter space

What all-sky low-latency searches are running?

Compact Binary Coalescence (CBC)

“Everything else” (Bursts)

What all-sky low-latency searches are running?

Compact Binary Coalescence (CBC)

- gstlal (lowmass)
- Multi-Band Transit Analysis (MBTA)

Both perform decompositions of large template banks and matched-filter data
Templates → assumed morphology

"Everything else" (Bursts)

What all-sky low-latency searches are running?

Compact Binary Coalescence (CBC)

- gstlal (lowmass)
- Multi-Band Transit Analysis (MBTA)

"Everything else" (Bursts)

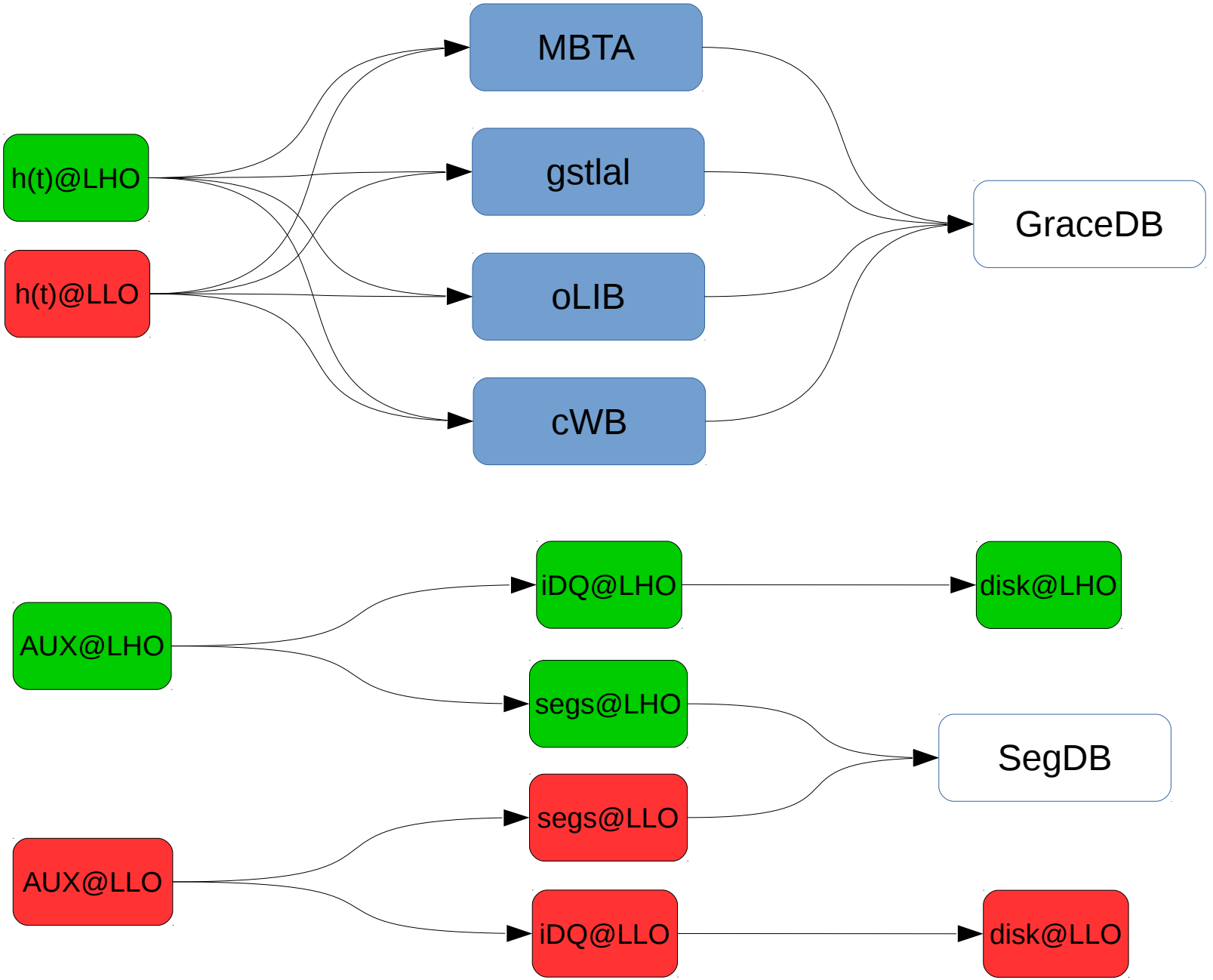
- Coherent WaveBurst (cWB)

cWB maximizes a "contrained" likelihood to reconstruct the waveform. Makes minimal assumptions about polarization (when possible).

- Omicron+LALInferenceBurst (oLIB)

oLIB performs incoherent coincidence with sineGaussian template (Omicron) before Computing fully coherent Bayes Factors (LIB) using a single sineGaussian template.

How are candidates reported internally?



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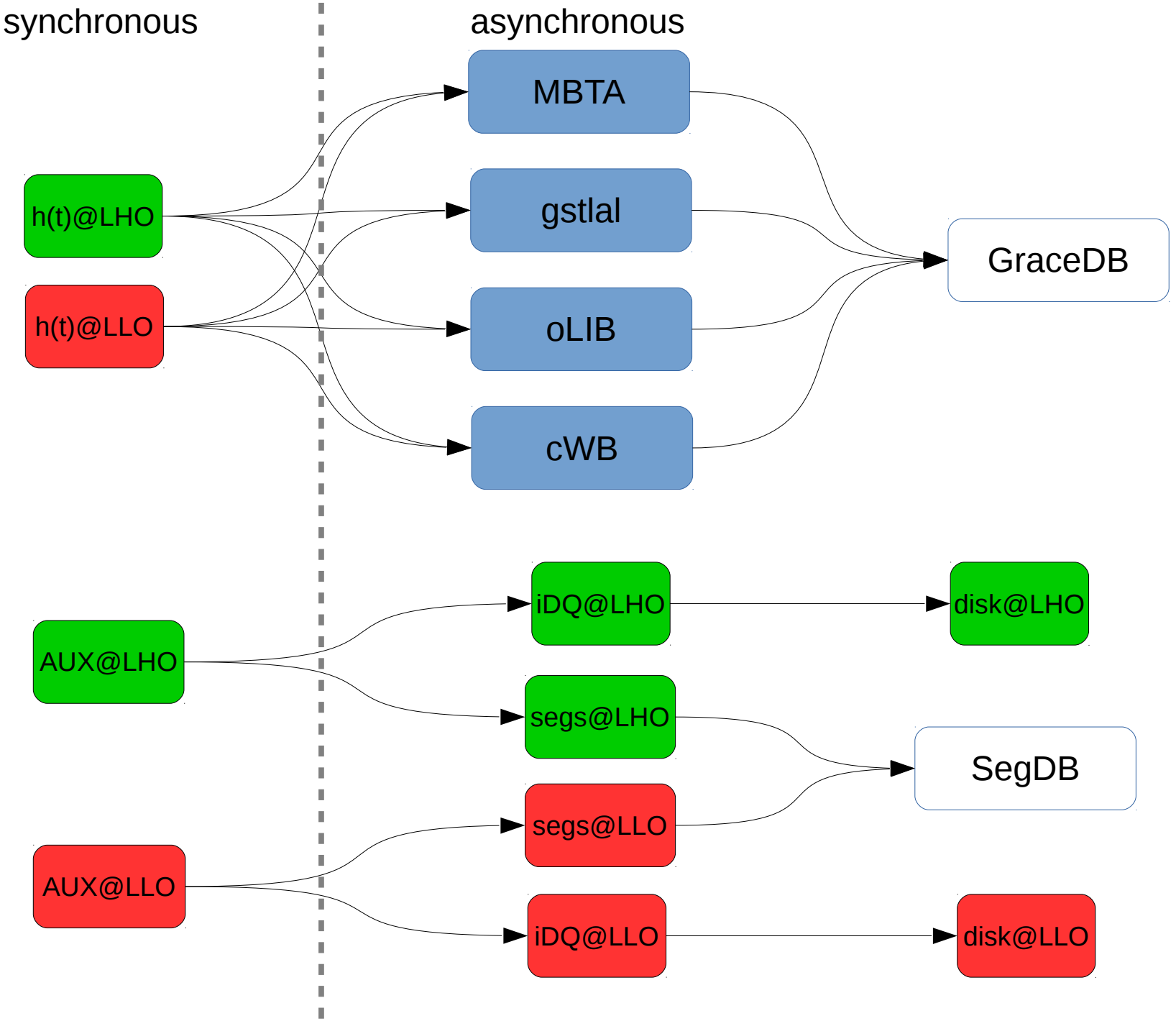

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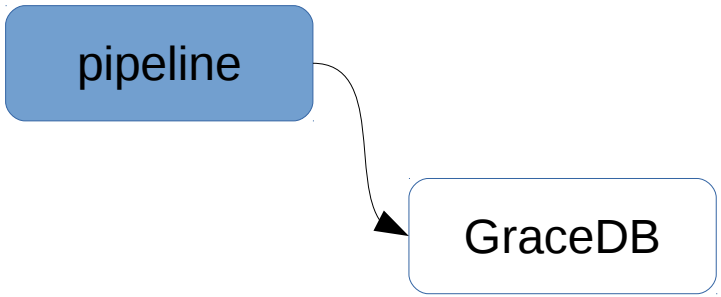

MOU partners

SegDB

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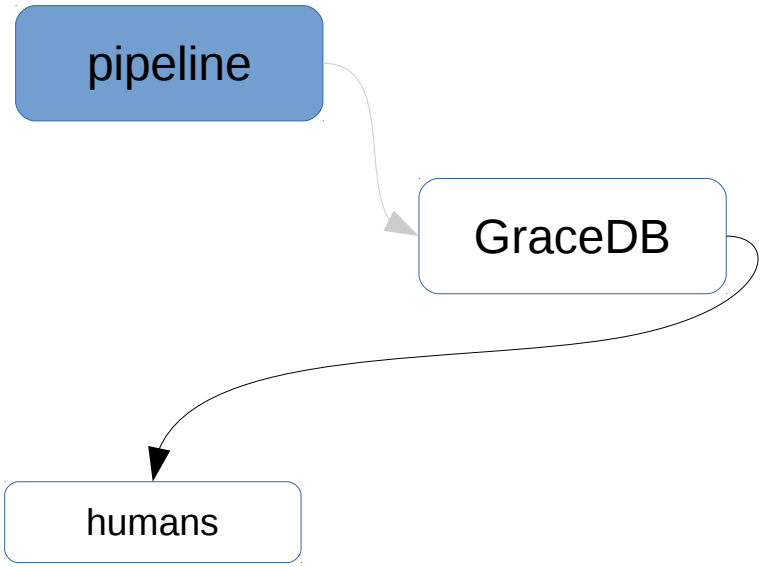

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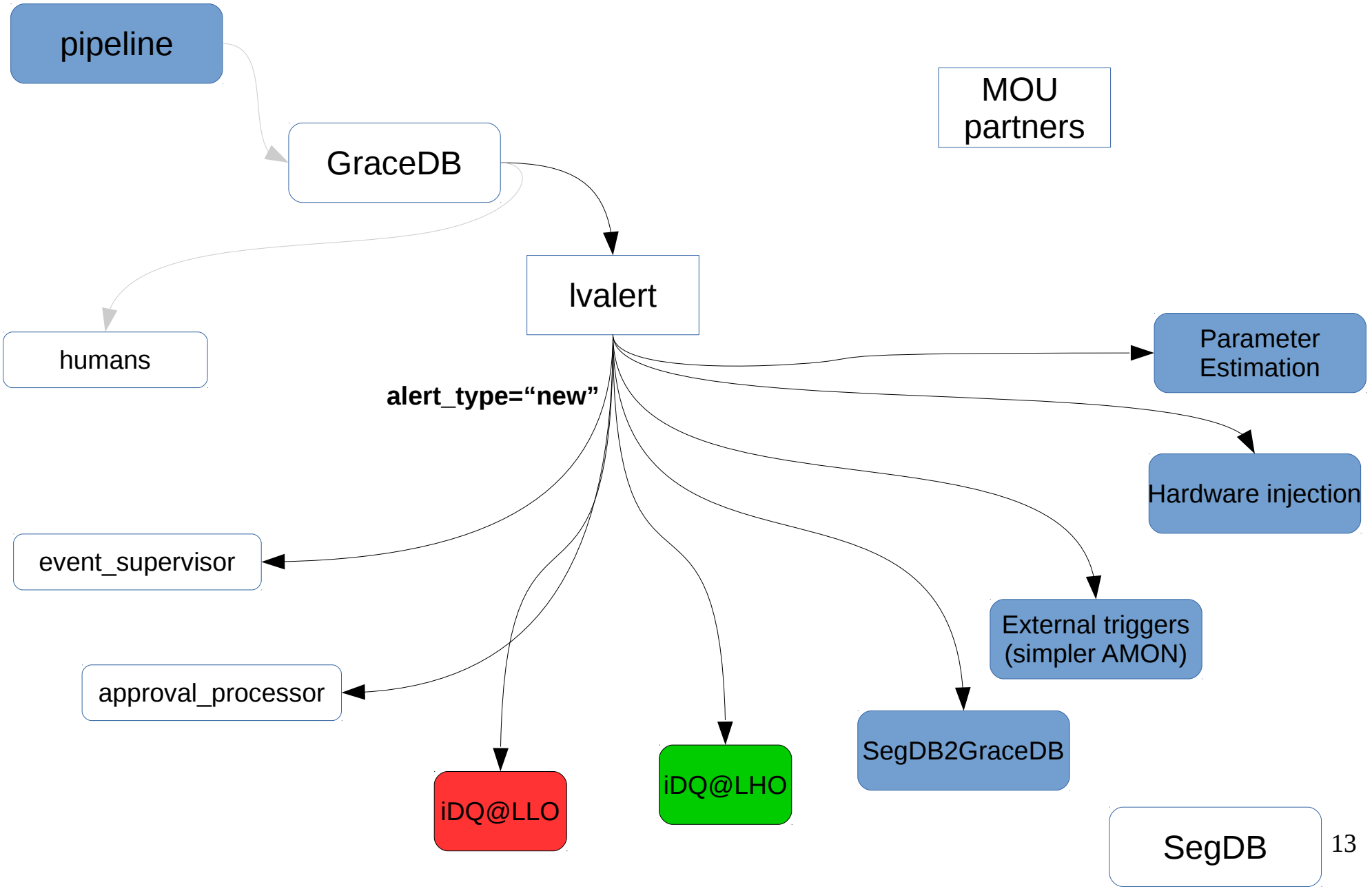

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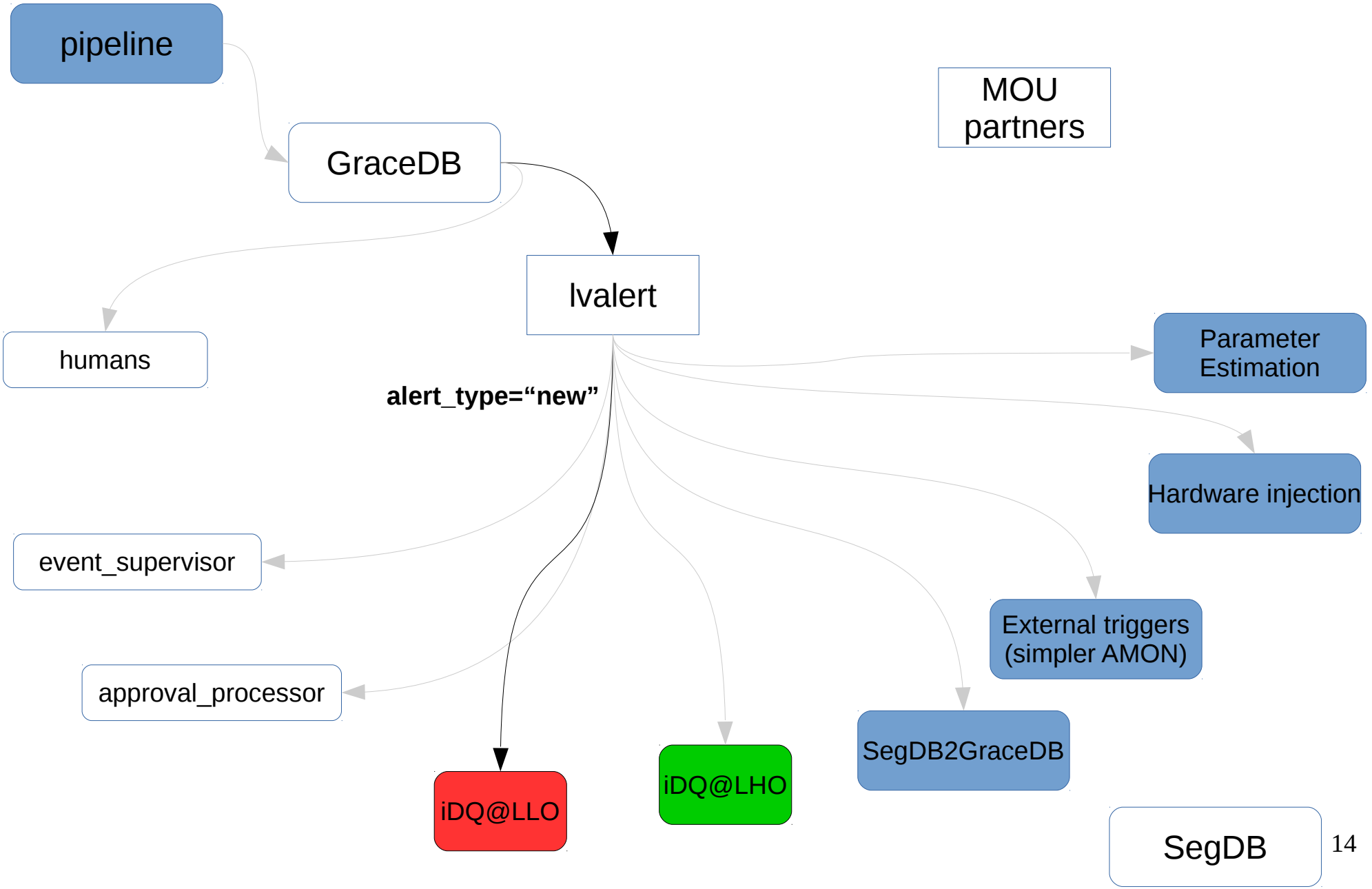

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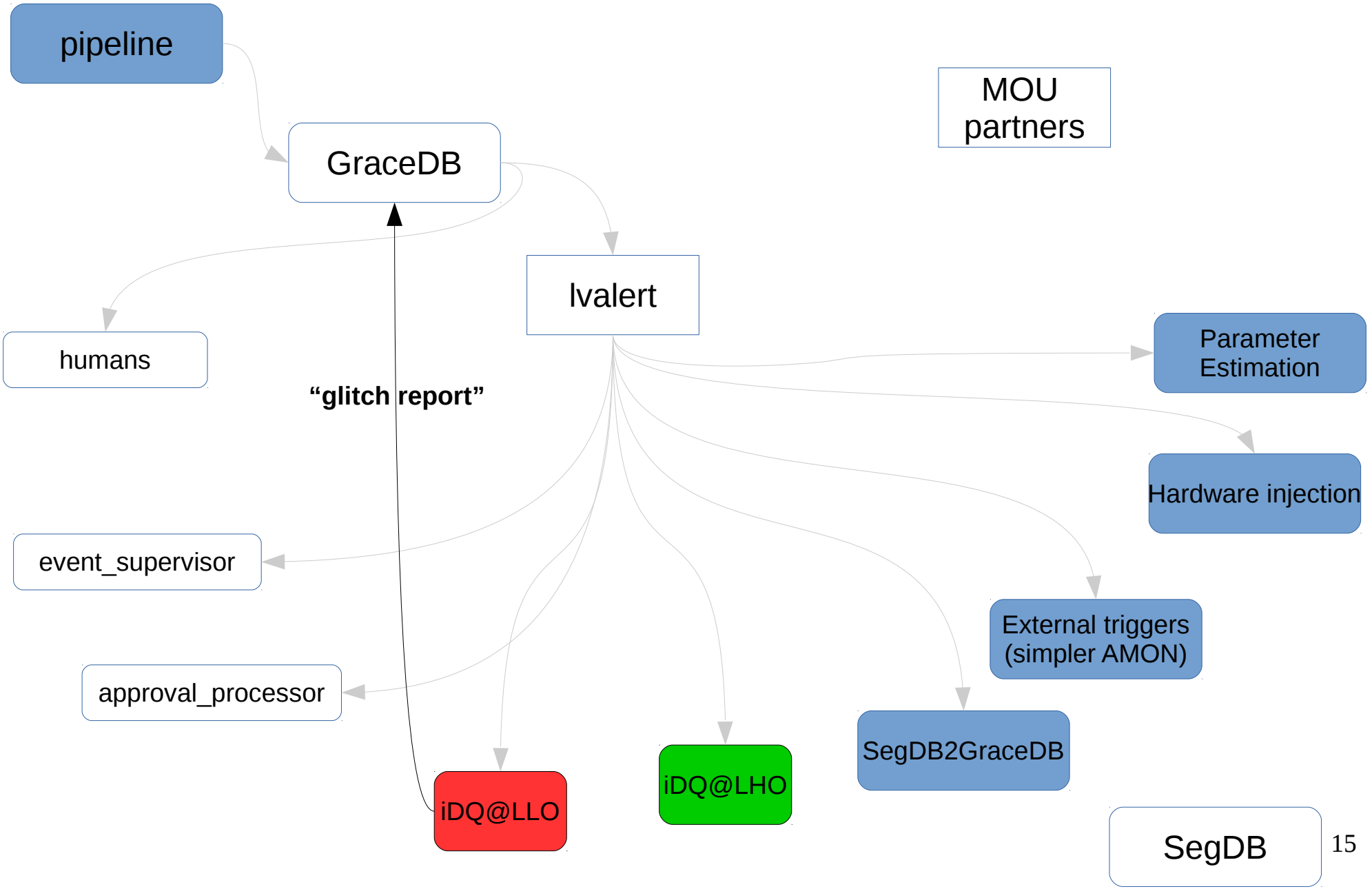

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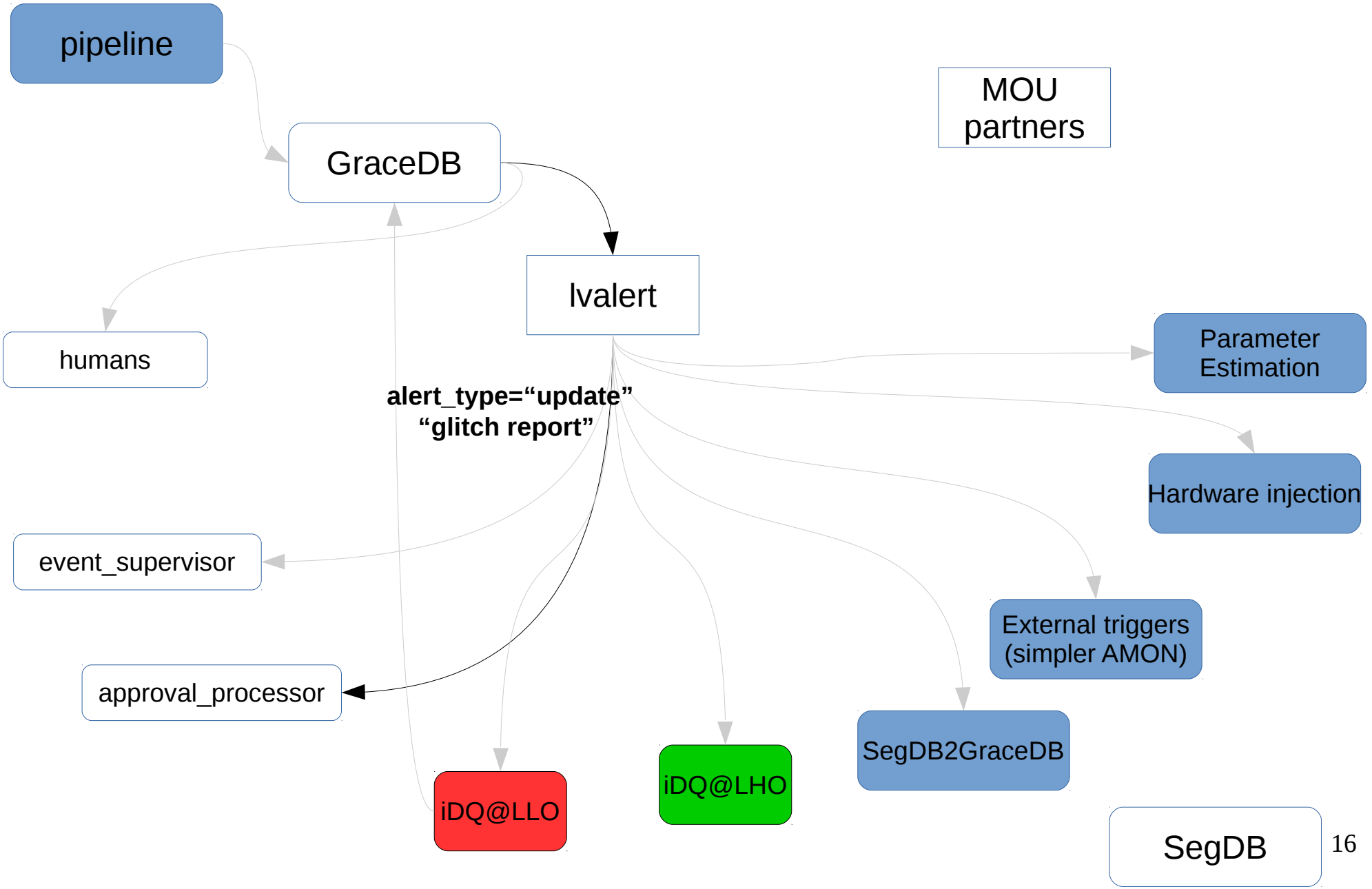

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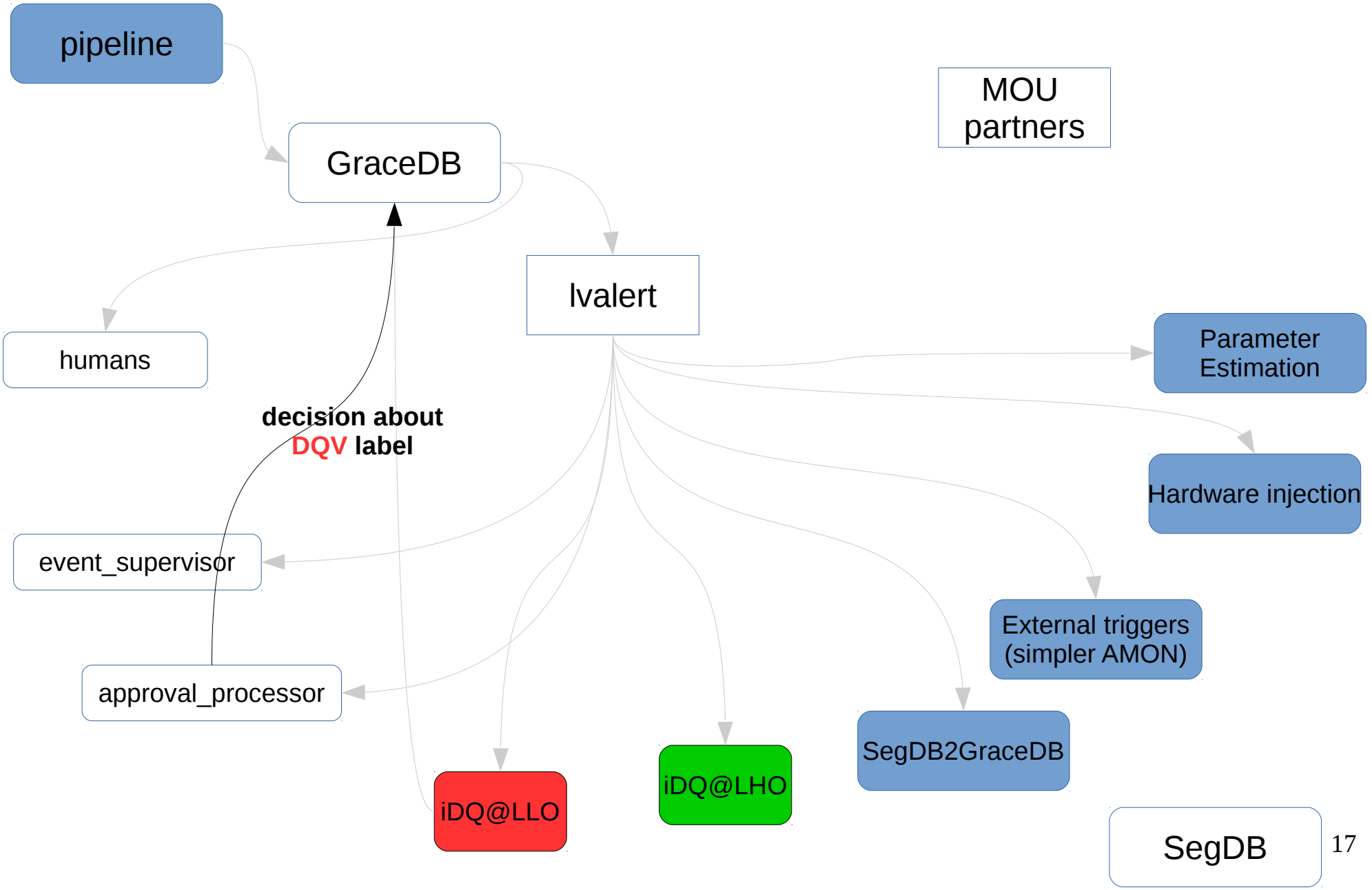

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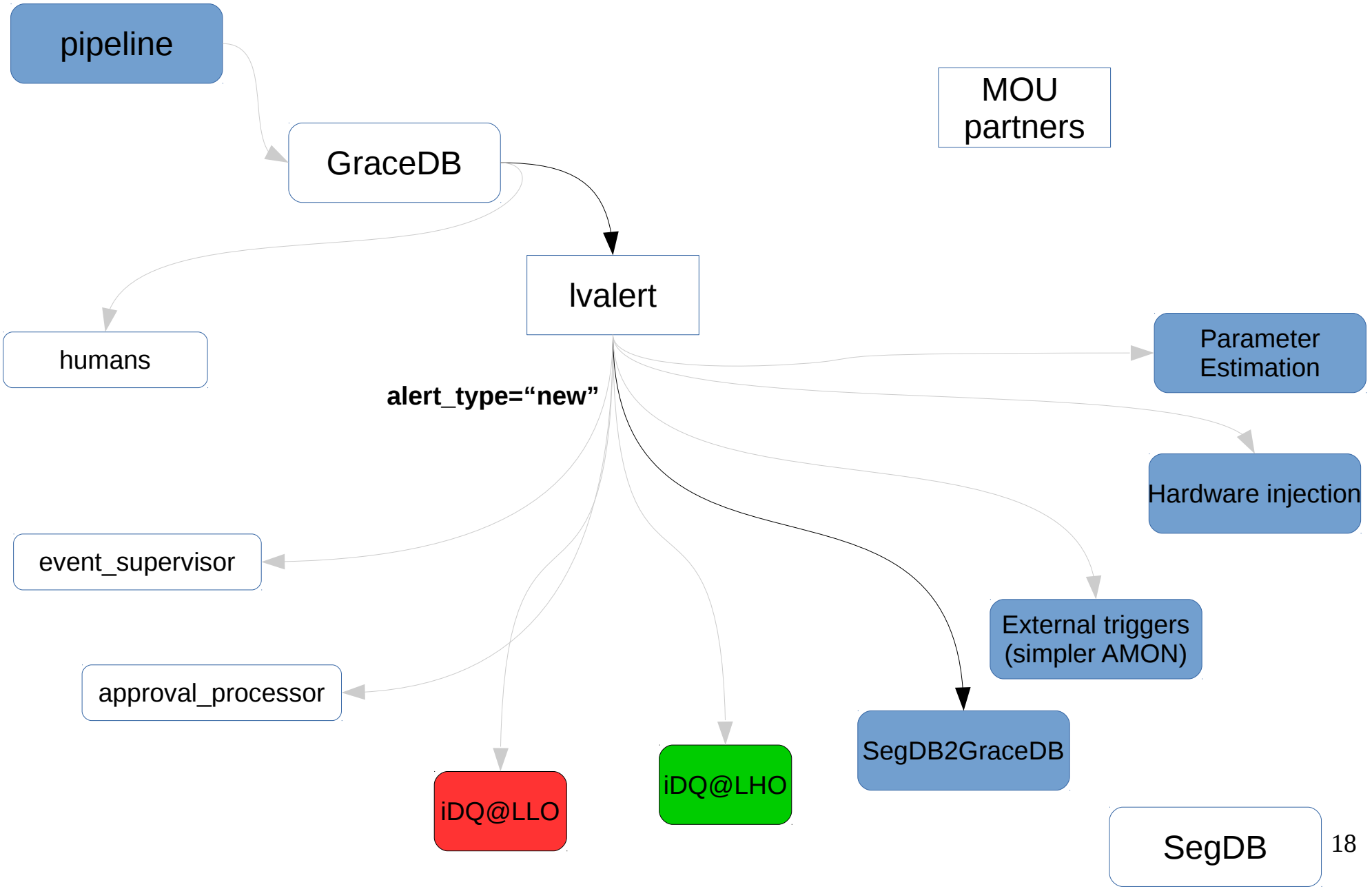

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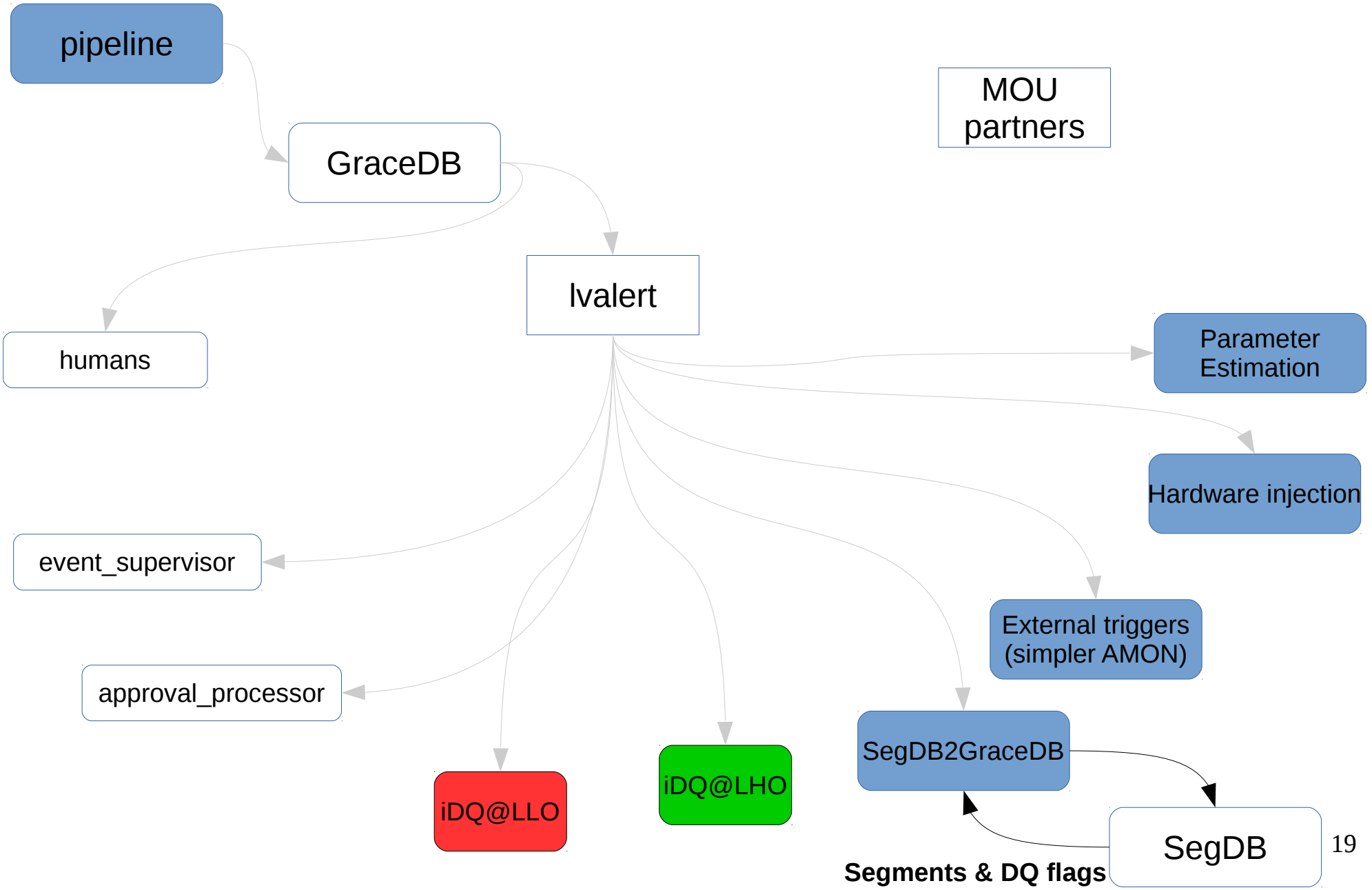

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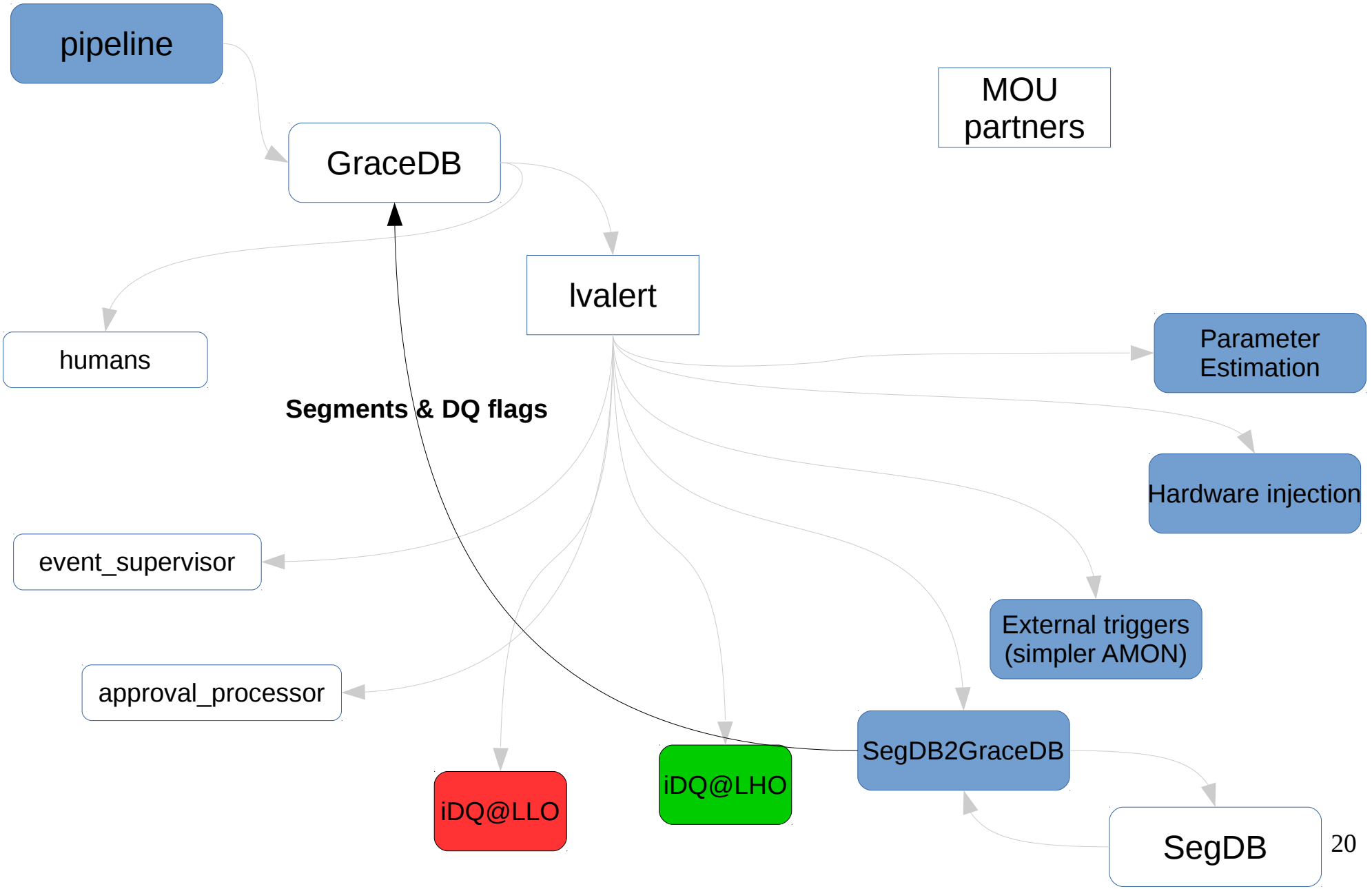

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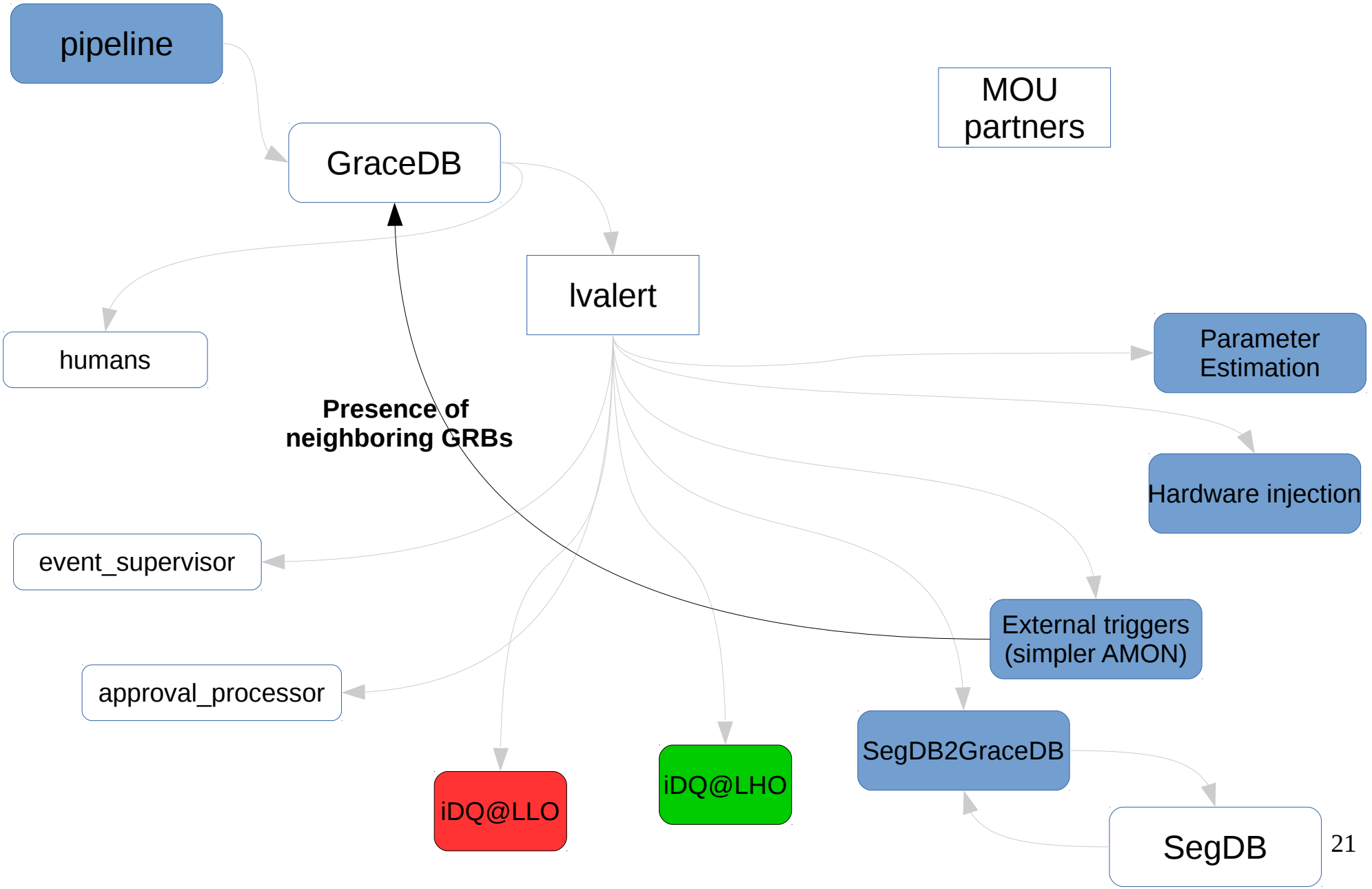

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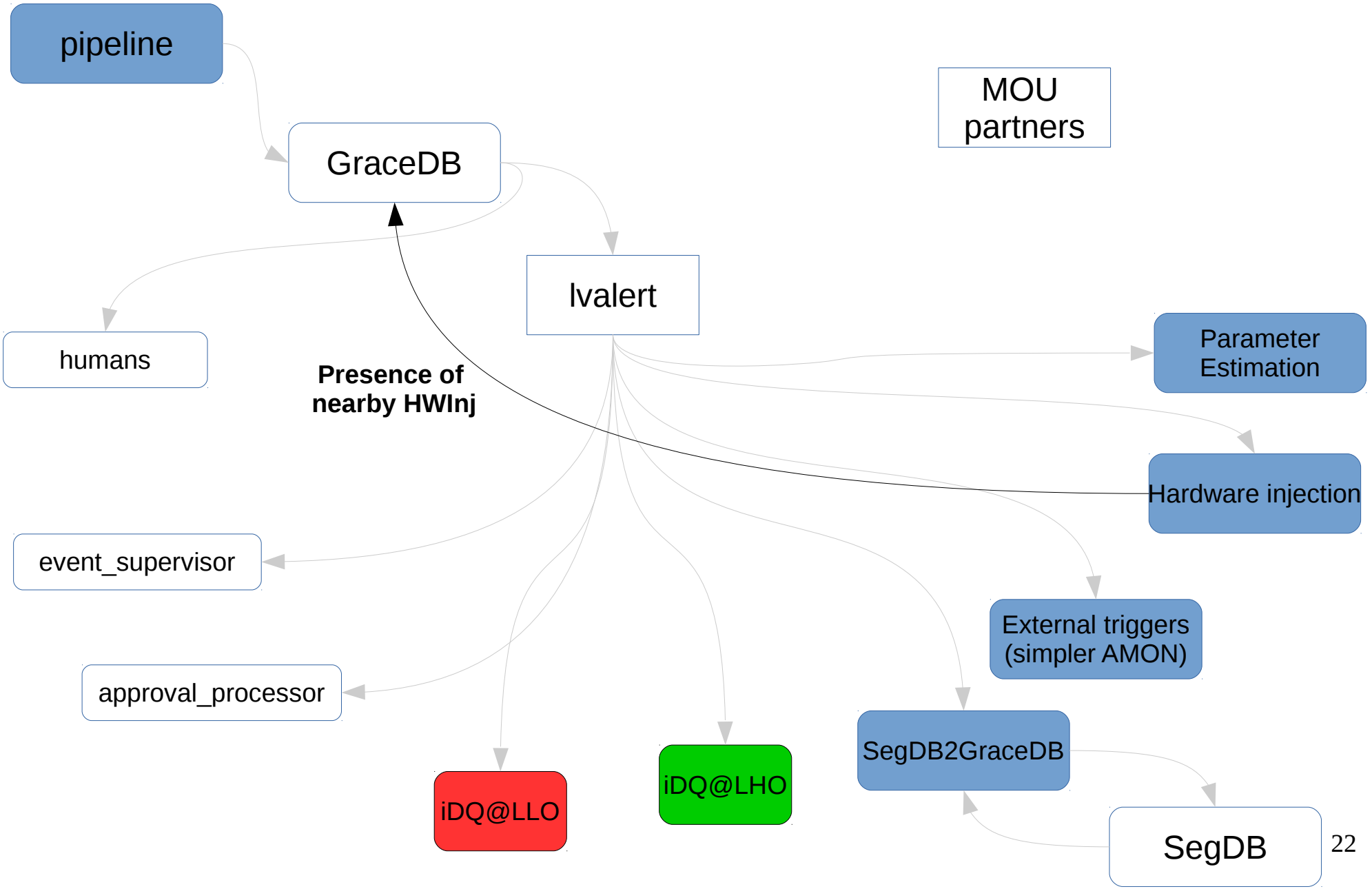

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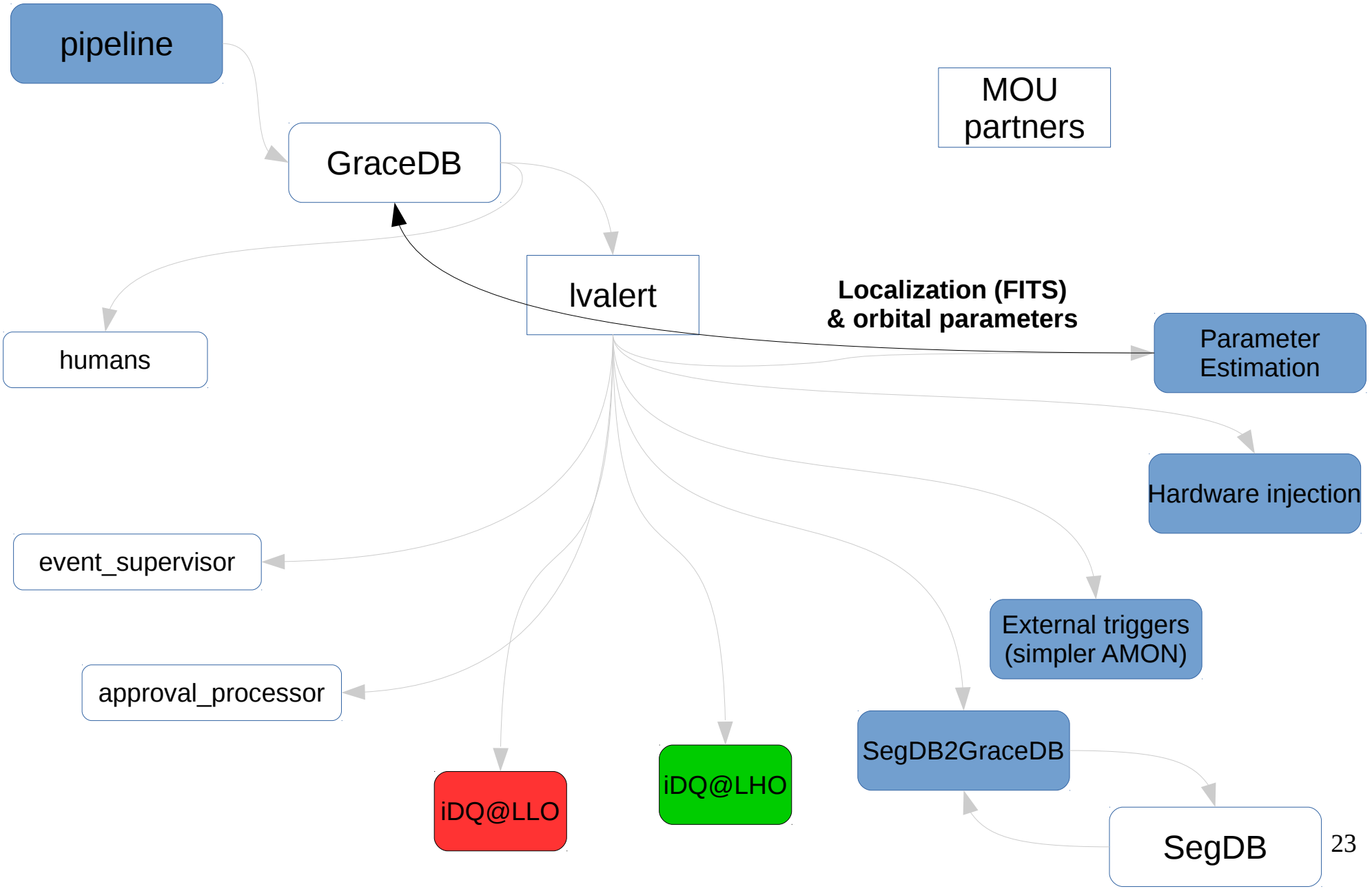

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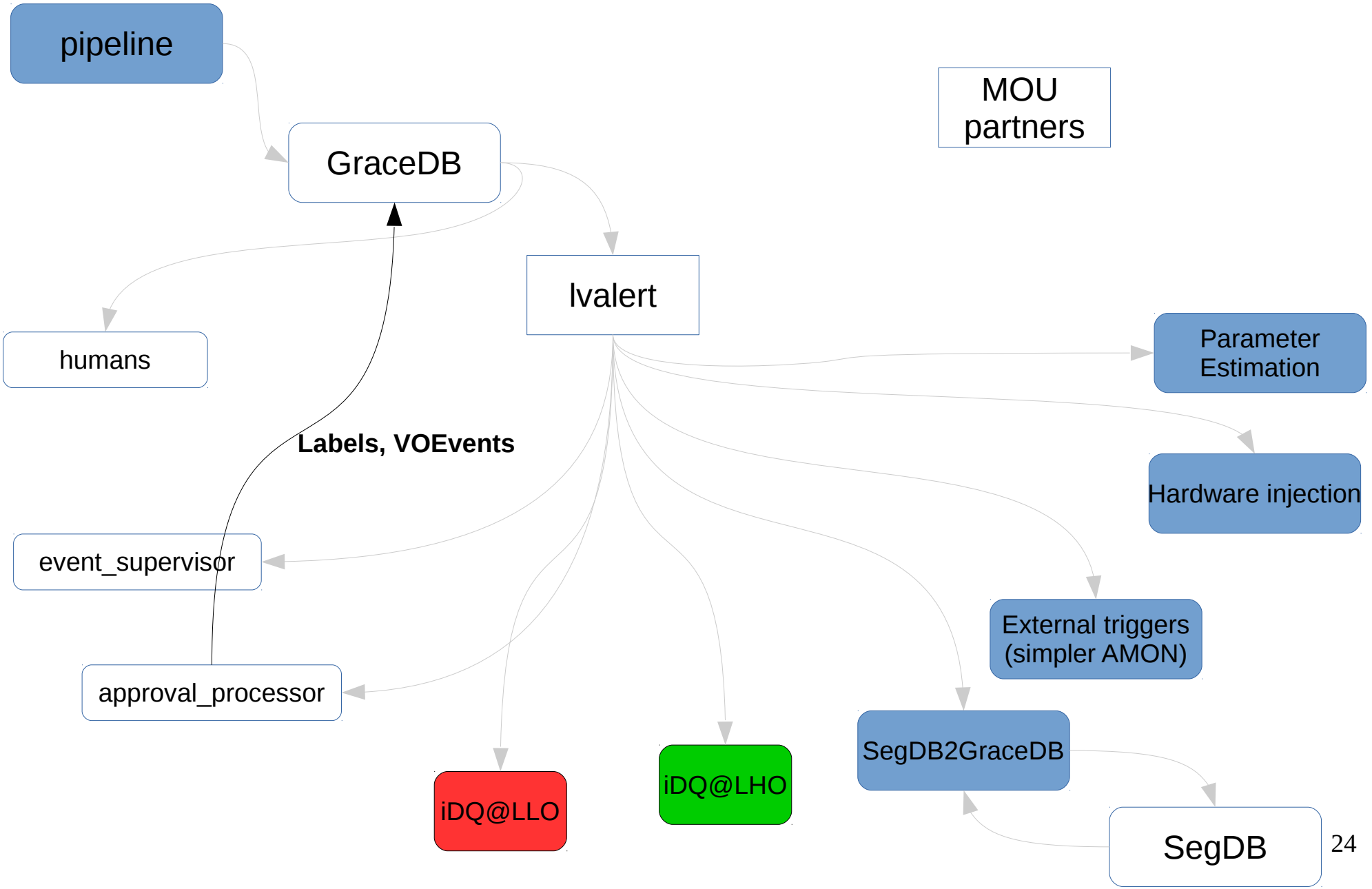

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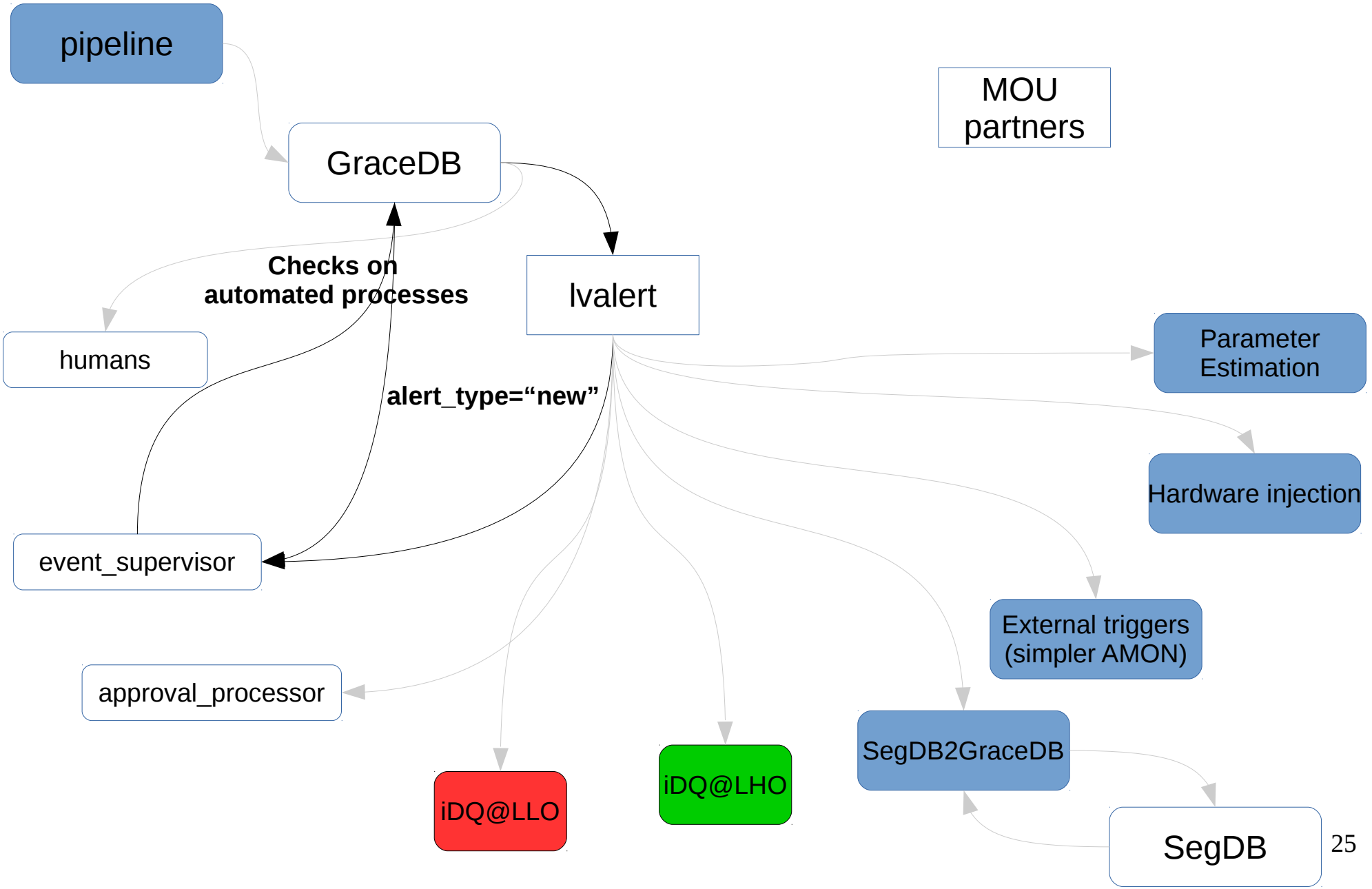

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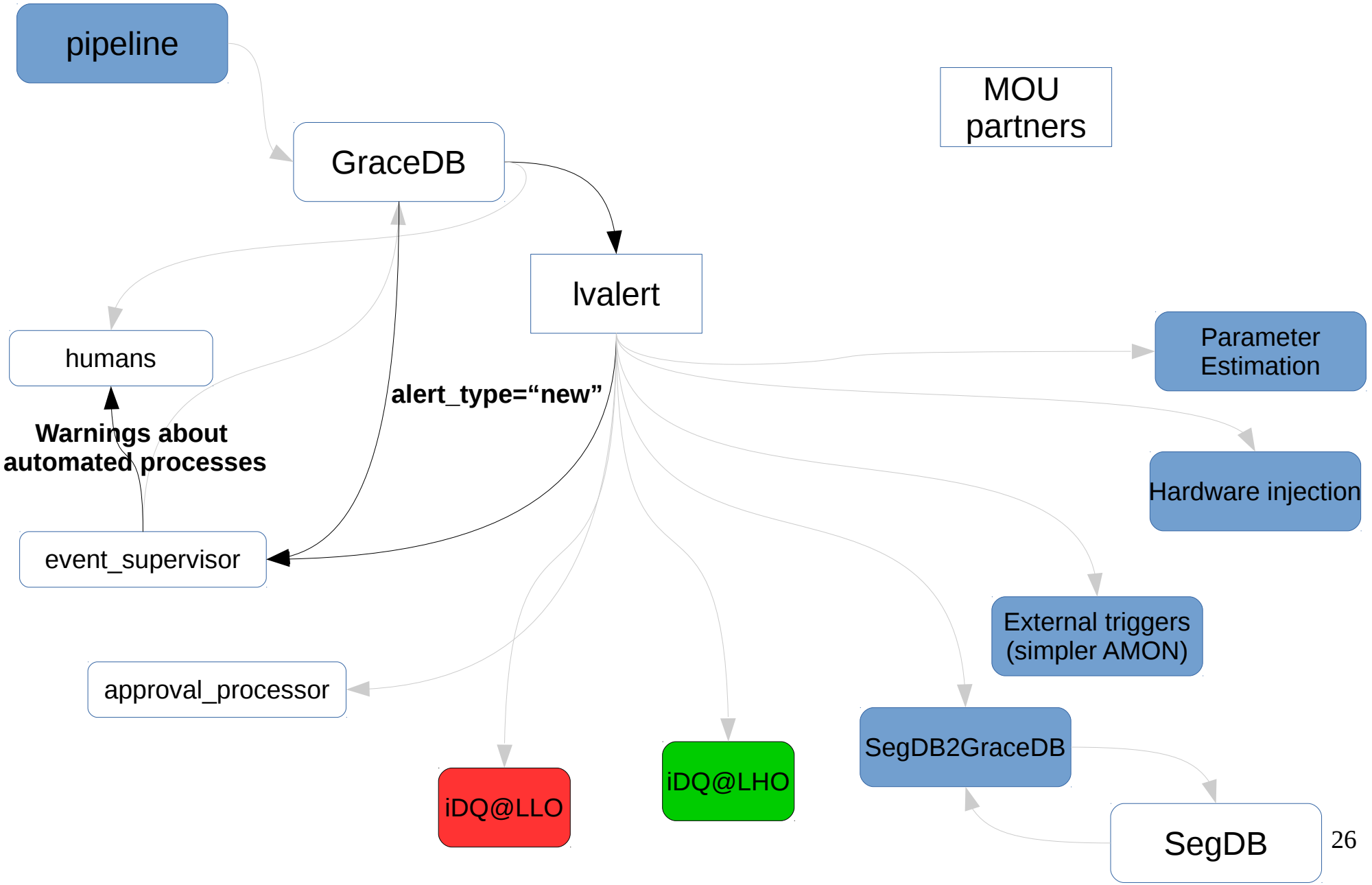

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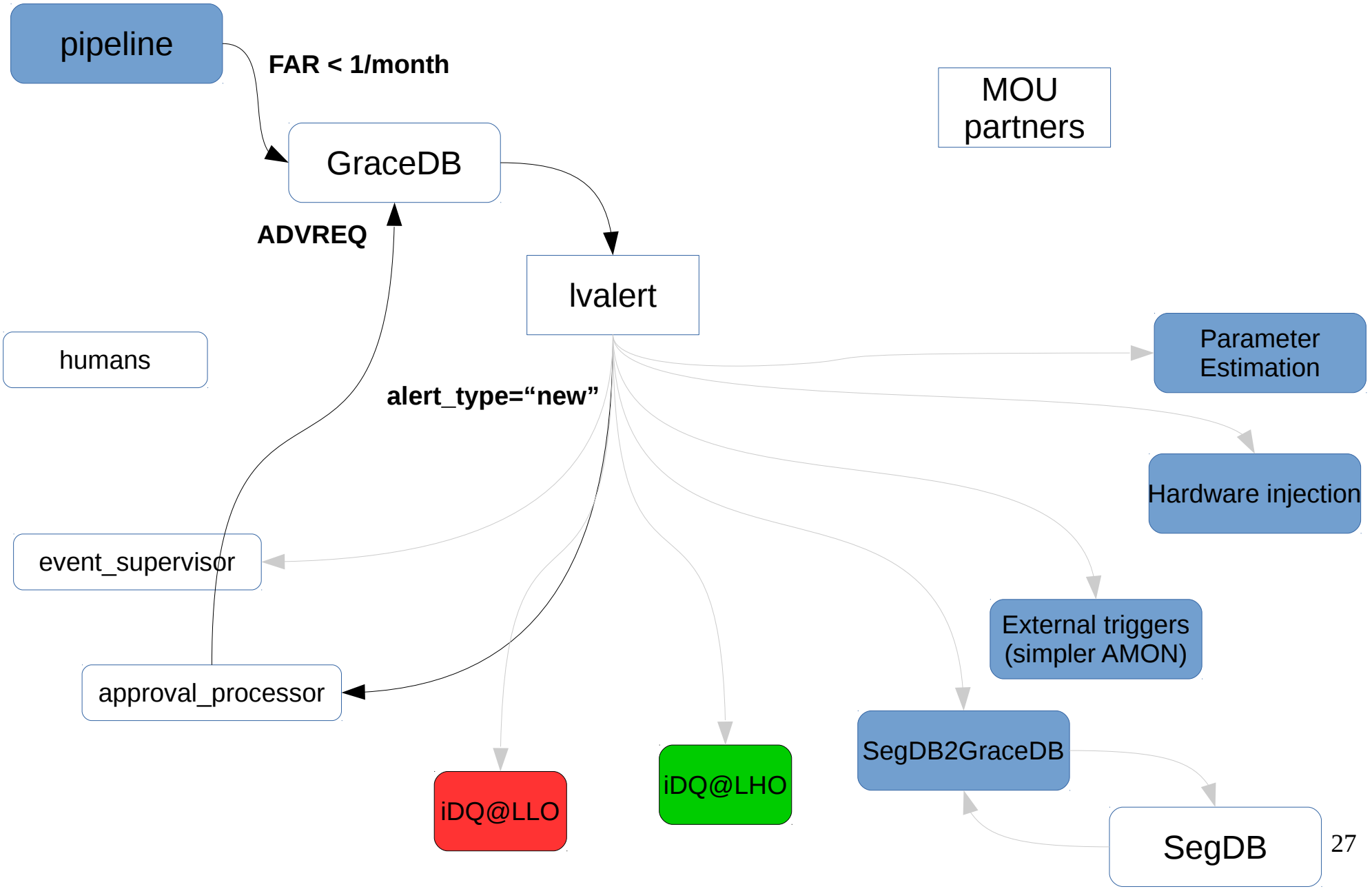

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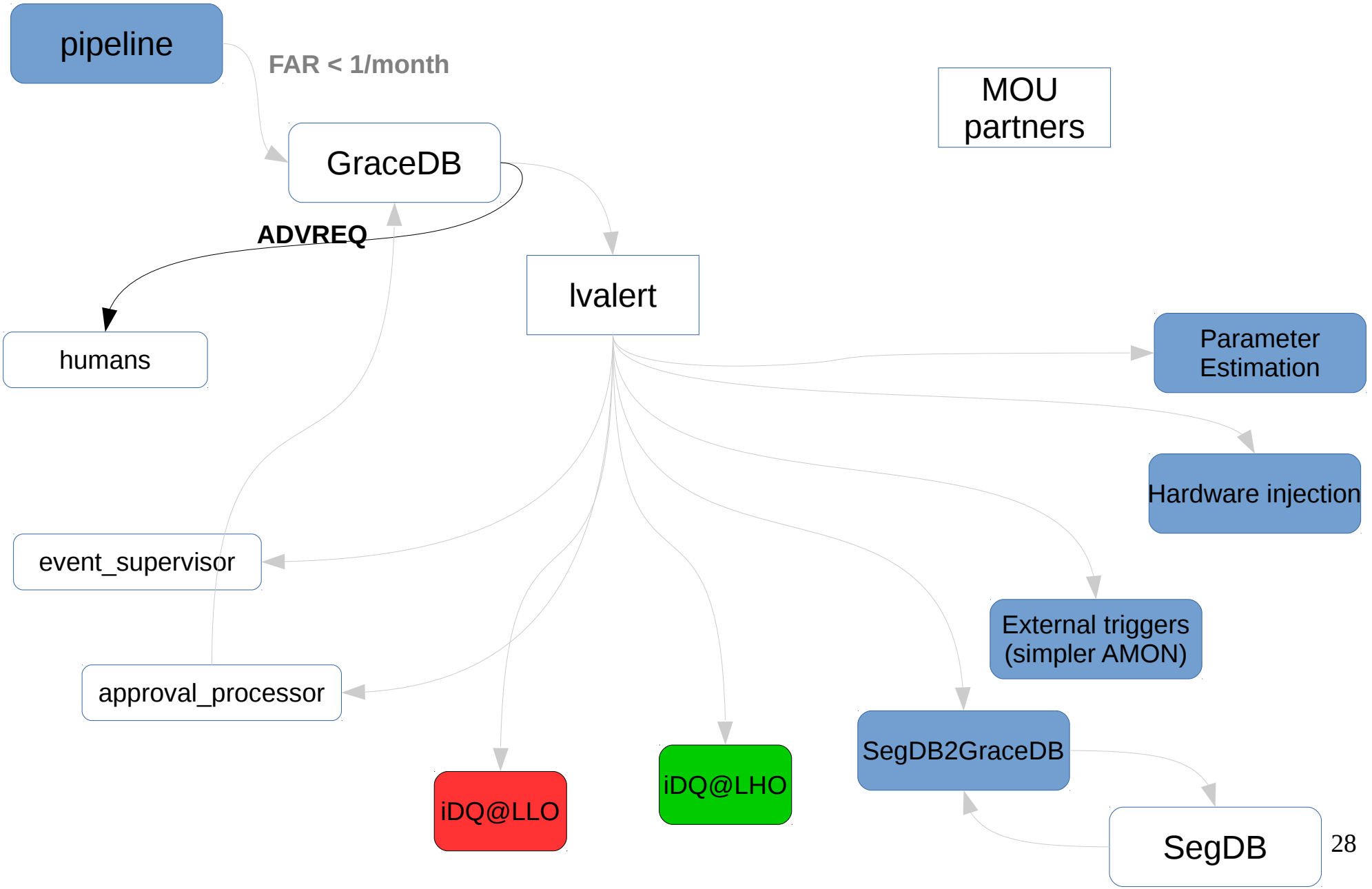

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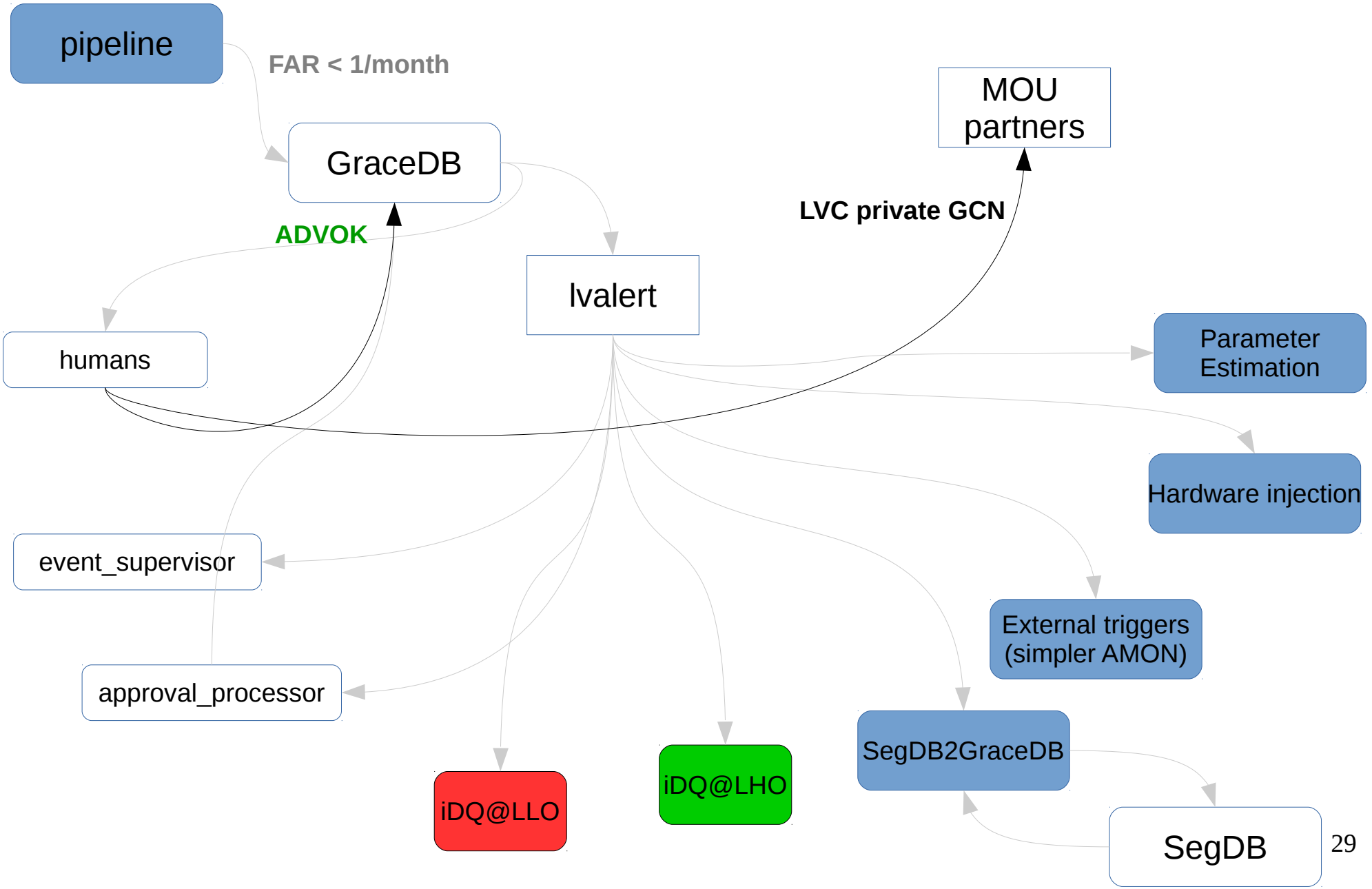

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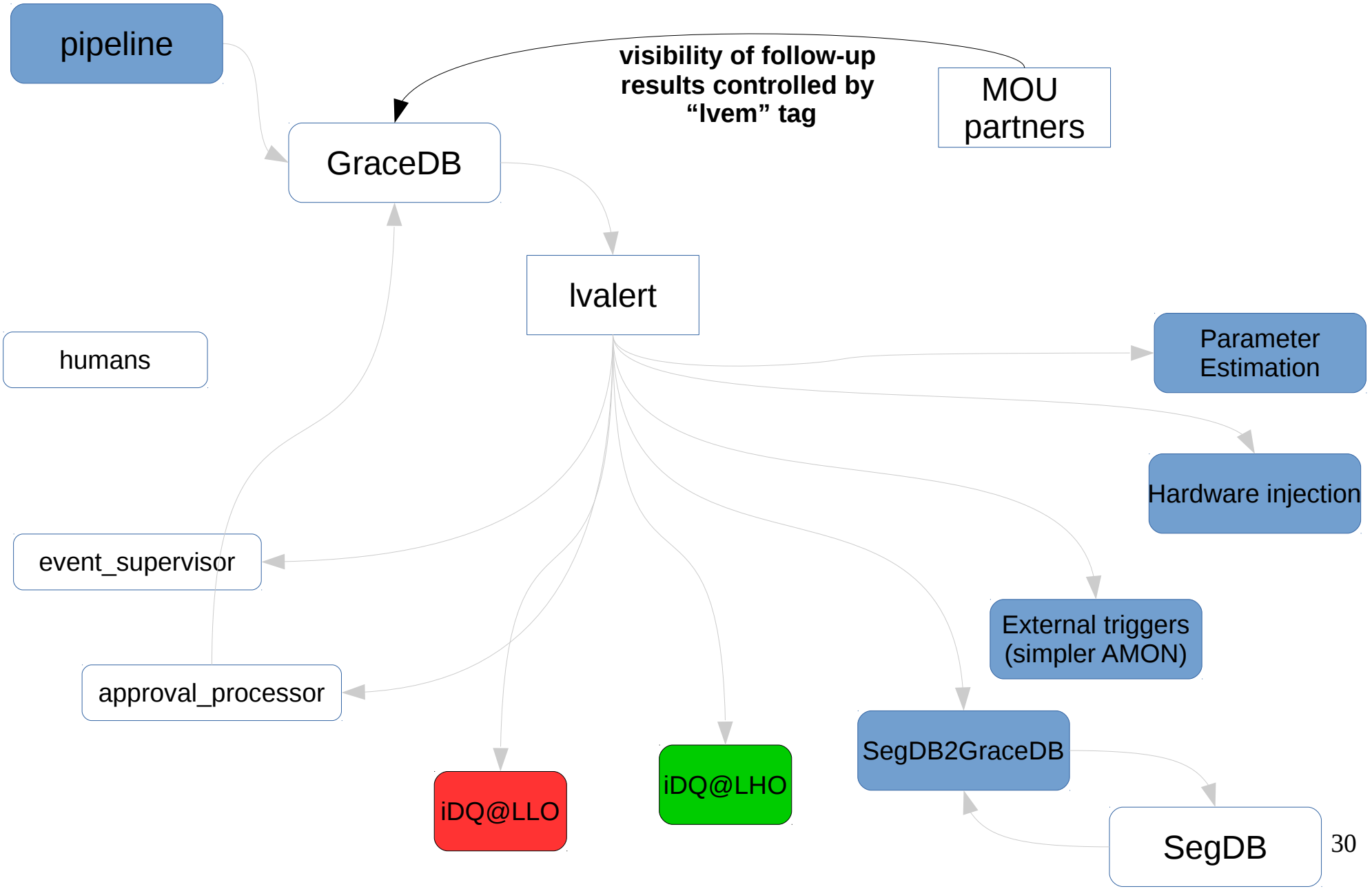

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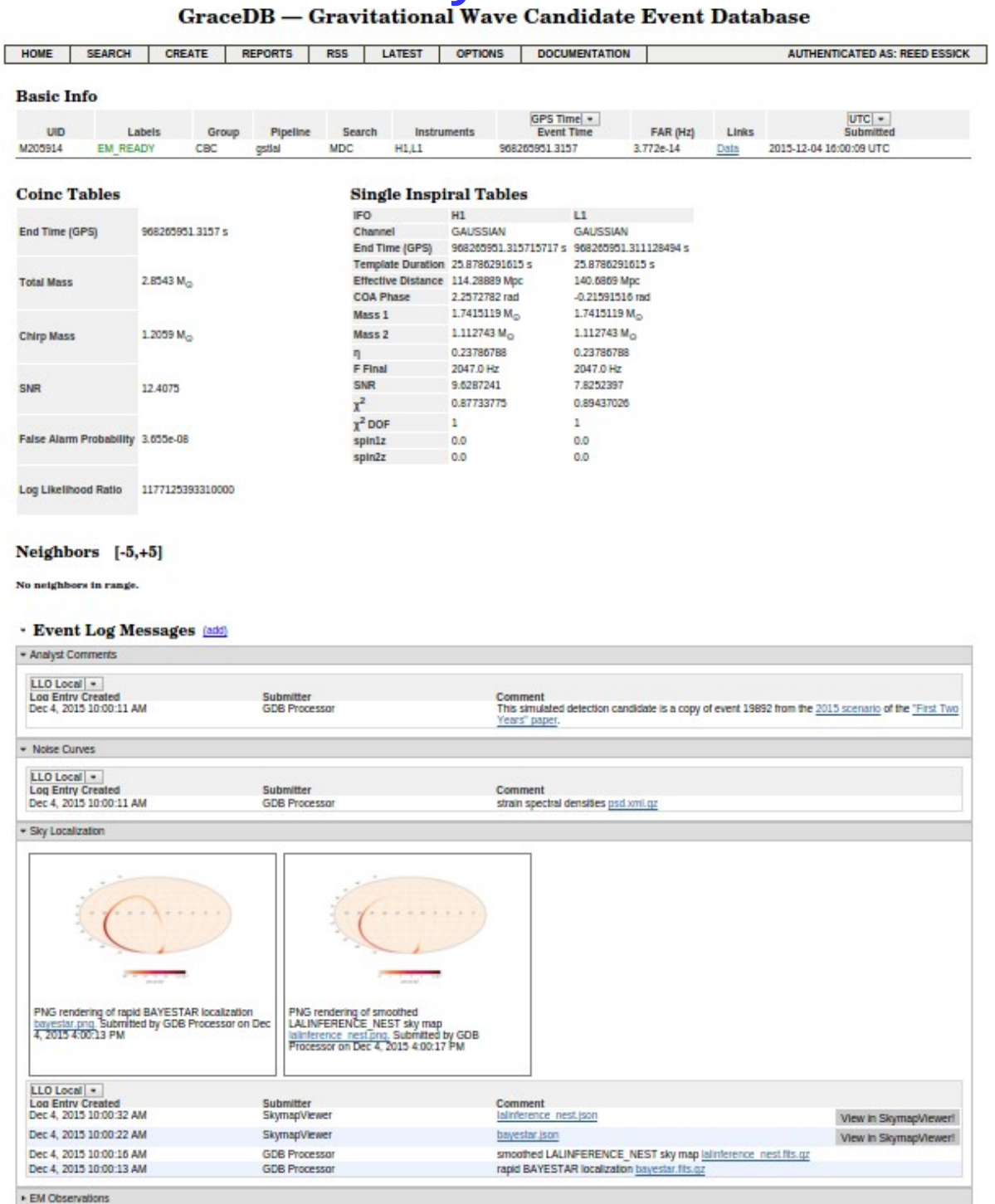
Basic information about the event

More detailed information (parameters reported by search)

Neighboring events (internal and external)

Comments and analysis input by hand

Localizations (HEALPix FITS files) Follow-up footprints and EM observations reported below



GraceDB — Gravitational Wave Candidate Event Database

HOME | SEARCH | CREATE | REPORTS | RSS | LATEST | OPTIONS | DOCUMENTATION | AUTHENTICATED AS: REED ESSICK

Basic Info

UID	Labels	Group	Pipeline	Search	Instruments	GPS Time Event Time	FAR (Hz)	Links	UTC Submitted
M205914	EM_READY	CBC	gstlal	MDC	H1,L1	968265951.3157	3.772e-14	Data	2015-12-04 16:00:09 UTC

Coinc Tables

End Time (GPS)	968265951.3157 s
Total Mass	2.8543 $M_\odot$
Chirp Mass	1.2059 $M_\odot$
SNR	12.4075
False Alarm Probability	3.655e-08
Log Likelihood Ratio	1177125393310000

Single Inspiral Tables

IFO	H1	L1
Channel	GAUSSIAN	GAUSSIAN
End Time (GPS)	968265951.315715717 s	968265951.311128494 s
Template Duration	25.8786291615 s	25.8786291615 s
Effective Distance	114.28889 Mpc	140.6869 Mpc
COA Phase	2.2572782 rad	-0.21591516 rad
Mass 1	1.7415119 $M_\odot$	1.7415119 $M_\odot$
Mass 2	1.112743 $M_\odot$	1.112743 $M_\odot$
η	0.23786788	0.23786788
F Final	2047.0 Hz	2047.0 Hz
SNR	9.6287241	7.8252397
χ^2	0.87733775	0.89437026
χ^2 DOF	1	1
spin1z	0.0	0.0
spin2z	0.0	0.0

Neighbors [-5,+5]

No neighbors in range.

Event Log Messages (add)

Analyst Comments

Log Entry Created	Submitter	Comment
Dec 4, 2015 10:00:11 AM	GDB Processor	This simulated detection candidate is a copy of event 19892 from the 2015 scenario of the "First Two Years" paper.

Noise Curves

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Dec 4, 2015 10:00:11 AM	GDB Processor	strain spectral densities psd.xml.gz

Sky Localization

PNG rendering of rapid BAYESTAR localization bayestar.png Submitted by GDB Processor on Dec 4, 2015 4:00:13 PM

PNG rendering of smoothed LALINFERENCE_NEST sky map lalinference_nest.png Submitted by GDB Processor on Dec 4, 2015 4:00:17 PM

Log Entry Created	Submitter	Comment	
Dec 4, 2015 10:00:32 AM	SkymapViewer	lalinference_nest.json	View in SkymapViewer!
Dec 4, 2015 10:00:22 AM	SkymapViewer	bayestar.json	View in SkymapViewer!
Dec 4, 2015 10:00:16 AM	GDB Processor	smoothed LALINFERENCE_NEST sky map lalinference_nest.fits.gz	
Dec 4, 2015 10:00:13 AM	GDB Processor	rapid BAYESTAR localization bayestar.fits.gz	

EM Observations

How are candidates circulated externally?

Private GCN notices
- currently written by hand.
- contain at least one FITS file and brief description of event.
- an “initial” alert rather than a “preliminary” alert.

What is in the MOU?
- Privacy rules:
  - who owns what data and with whom can it be shared?
- Publication rules:
  - possible counterparts embargoed until GW event published.
  - LVC will provide “detailed information” prior to publication.

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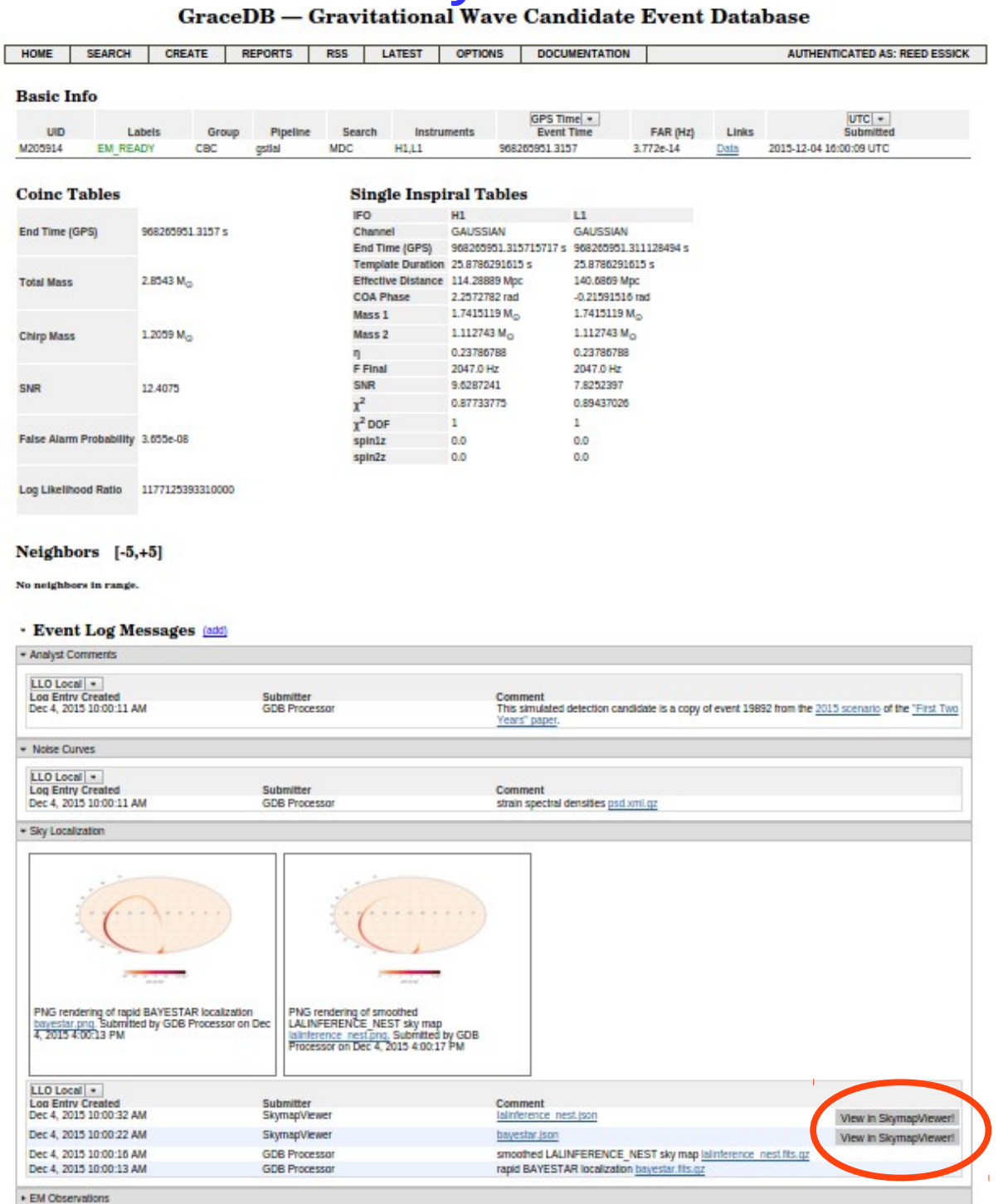

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EM Observations

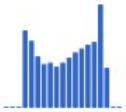
How is follow-up coordinated externally?

Skymap Viewer

A sky atlas for understanding LIGO-Virgo skymaps. Help here, and skymaps here. If you do not see the big dark sky map, look below and widen your browser. Zoom with the + and - at the right of the sky.

LIGO-Virgo Skymaps

This skymap is from GraceDB candidate **M205793**.
50% area = 276.2 sq deg
90% area = 954.0 sq deg



Show Weighted Galaxies (or table).

Time and Place

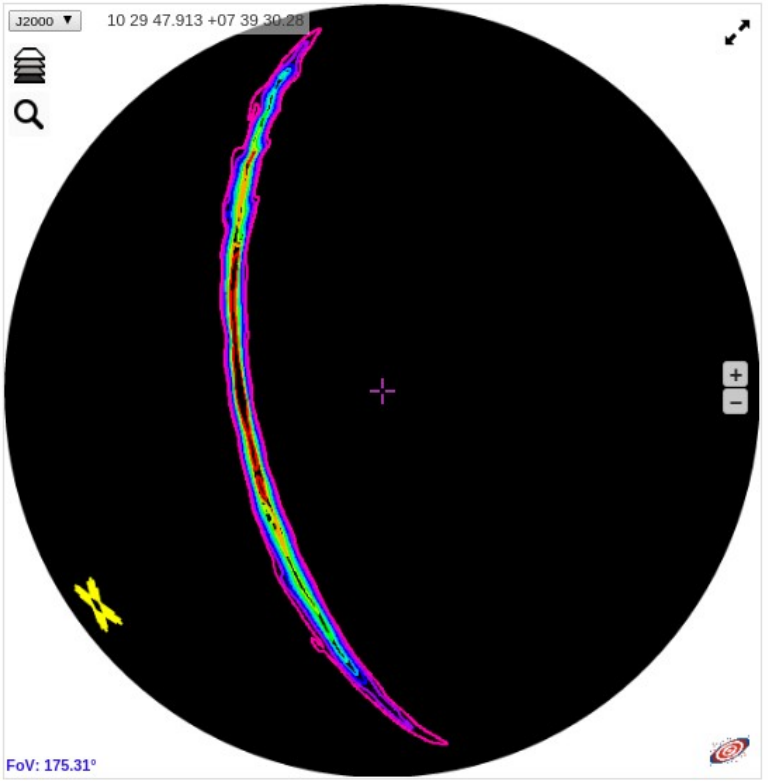
Universal time
2010-10-12T17:59:47 Now
E Longitude east lo Latitude latitude
Show Sky
Sun = and = Moon

Catalog Sources

Click the Layers icon to switch on catalogs. If you click on the sources on the sky, information will appear here with links to Simbad and NED.

Zoomable Multiwavelength Sky

Zoom in on the sky with the mouse or the +/- icons on the right of the sky. To change the image layer, click the Layers icon and select on Base image layer. Select the DSS rather than Mellinger to get better fine detail.



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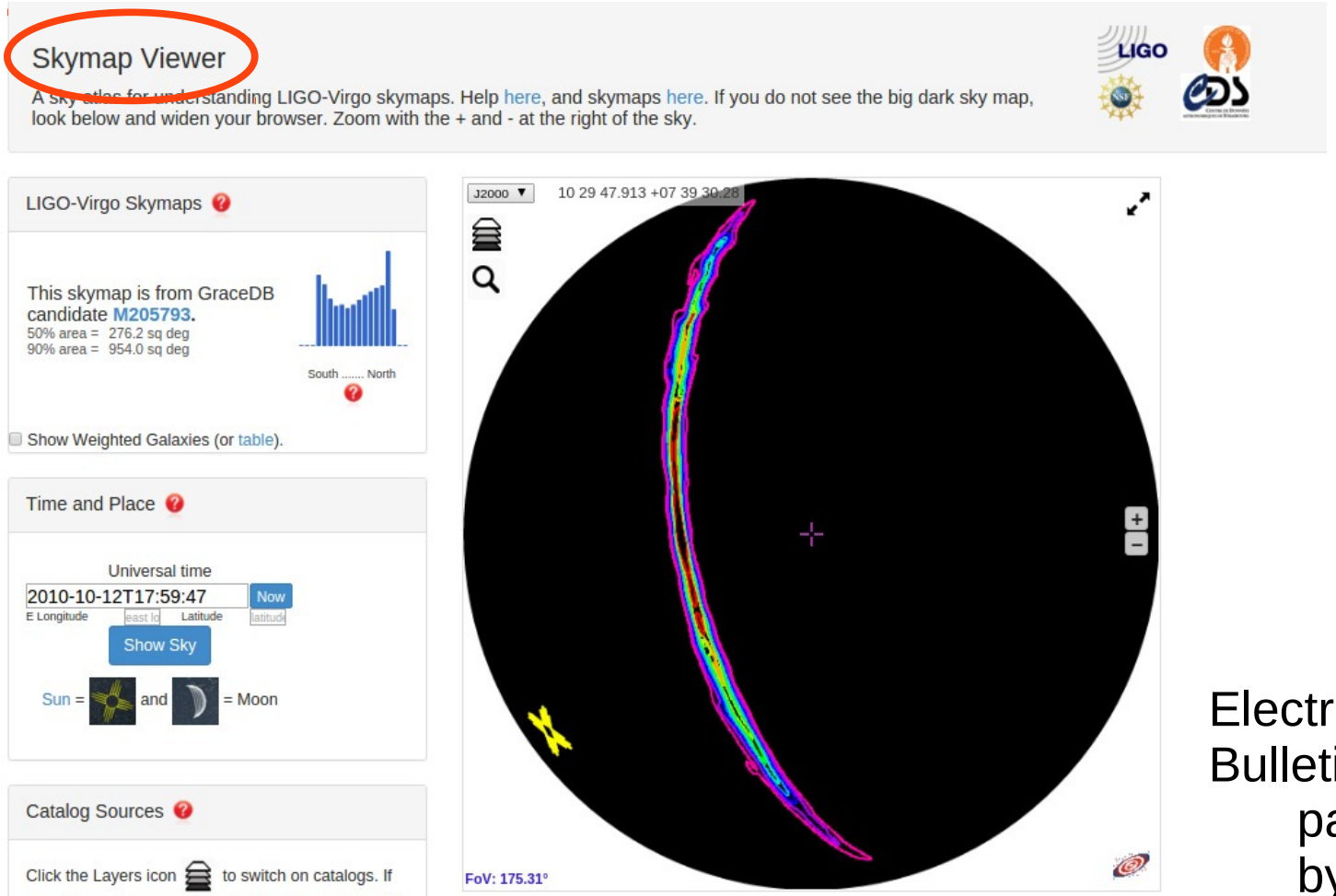

Electro-Magnetic Bulletin Board (EMBB)

part of GraceDB accessible by MOU partners.

EMBB Event Log (EEL)

Standardized format for reporting observation footprints to EMBB.

What to expect from LVC alerts

CBC alerts

Burst alerts

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CBC alerts

- Initial
  - search's point estimates
  - Bayestar localization
- Updates
  - LALInference posterior distributions
  - LALInference localization

Burst alerts

What to expect from LVC alerts

CBC alerts
- Initial
  - search's point estimates
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- Updates
  - LALInference posterior distributions
  - LALInference localization

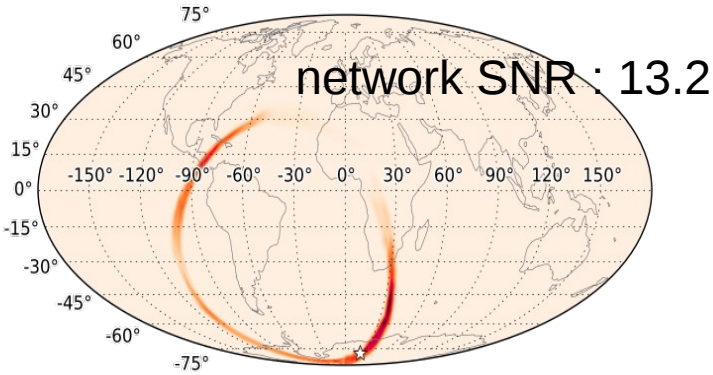
Burst alerts
- Initial
  - search's point estimates
  - cWB (or LIB PE) localization
- Updates
  - LIB PE localization
  - BayesWave waveform reconstruction
  - BayesWave localization

Public Data

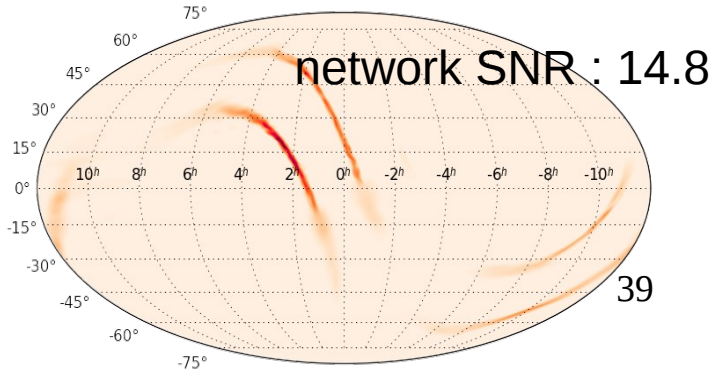
Technical documentation, tutorials, and instructions for registering for LV-EM services
https://gw-astronomy.org/wiki/LV_EM/TechInfo

LIGO Open Science Center (LOSC) provides instructions on how to access and manipulate archival LIGO data. A variety of formats are provided as well data quality information.
S5 data : 2005 - 2007
S6 data : 2009 - 2010

BNS F2Y OpenData : arXiv:1404.5623
A large-scale MDC study of detectability of BNS signals in both Gaussian and re-colored noise. Provides estimates on the expected detection rate as well as a large catalog of Bayestar and LALInference localizations.



Burst F2Y OpenData arXiv:1409.2435
A large-scale MDC study of burst localizations in Gaussian noise. Makes no predictions for detection rate. Provides a large catalog of cWB and LIB localizations.



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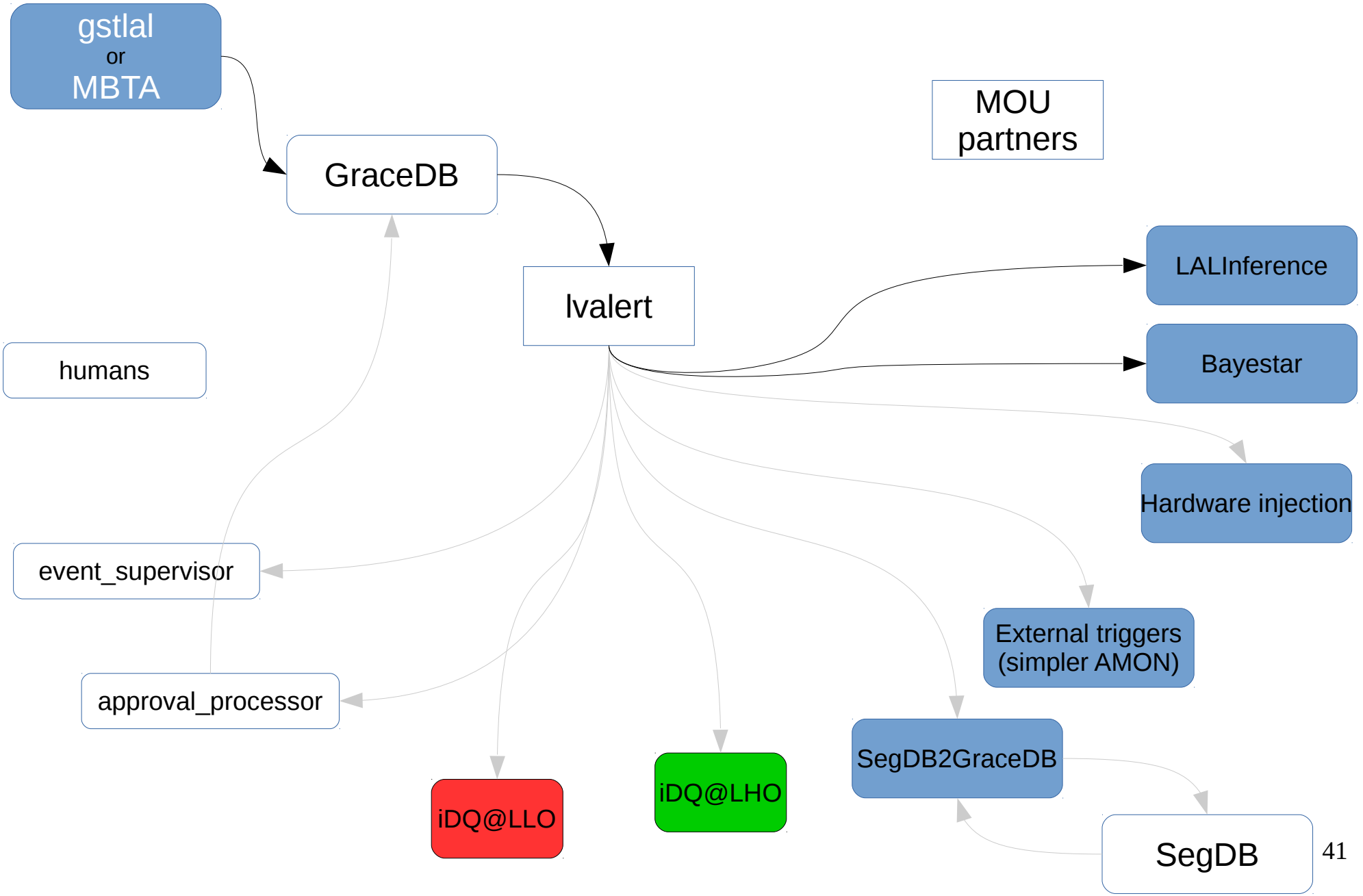

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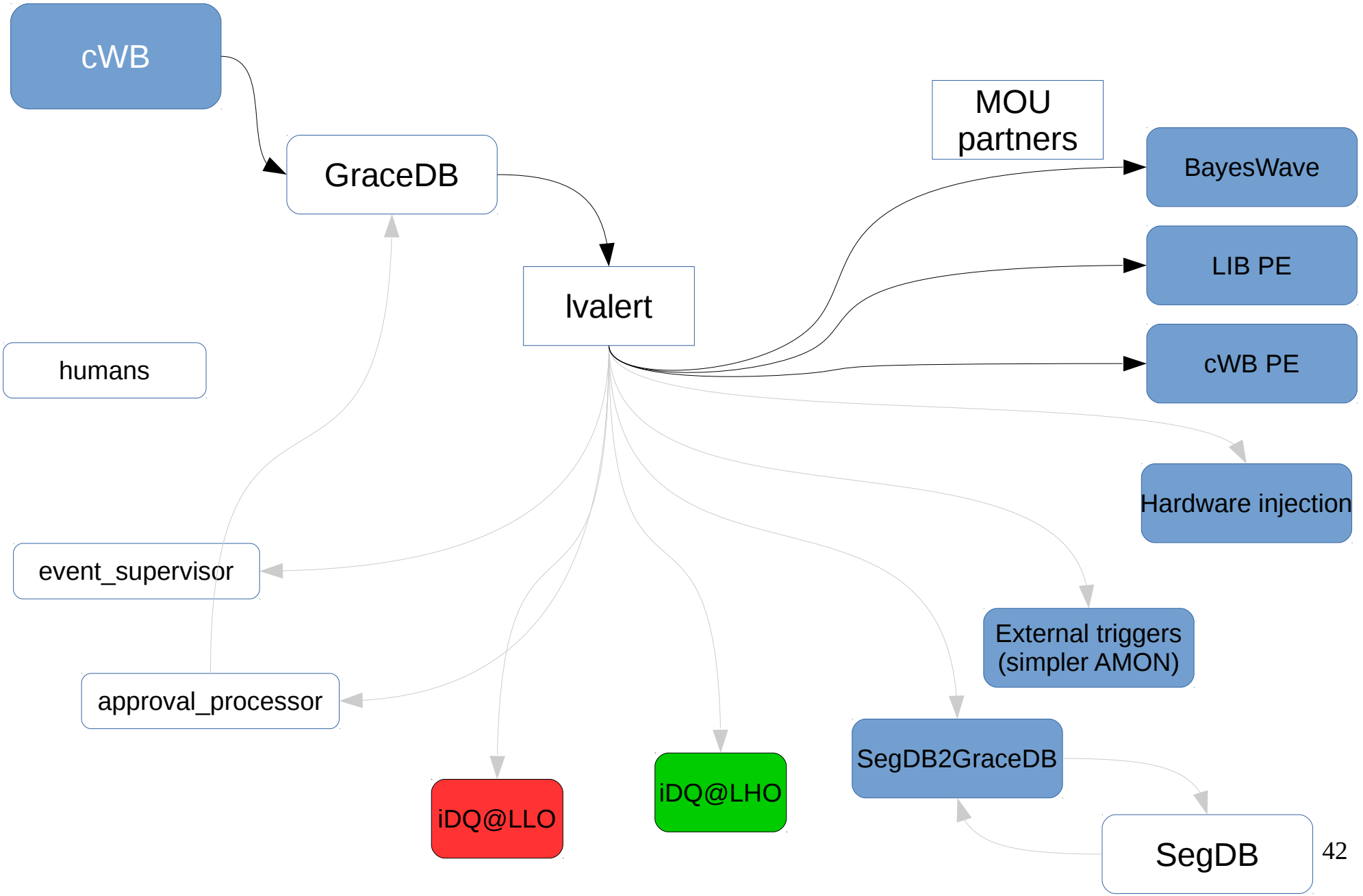

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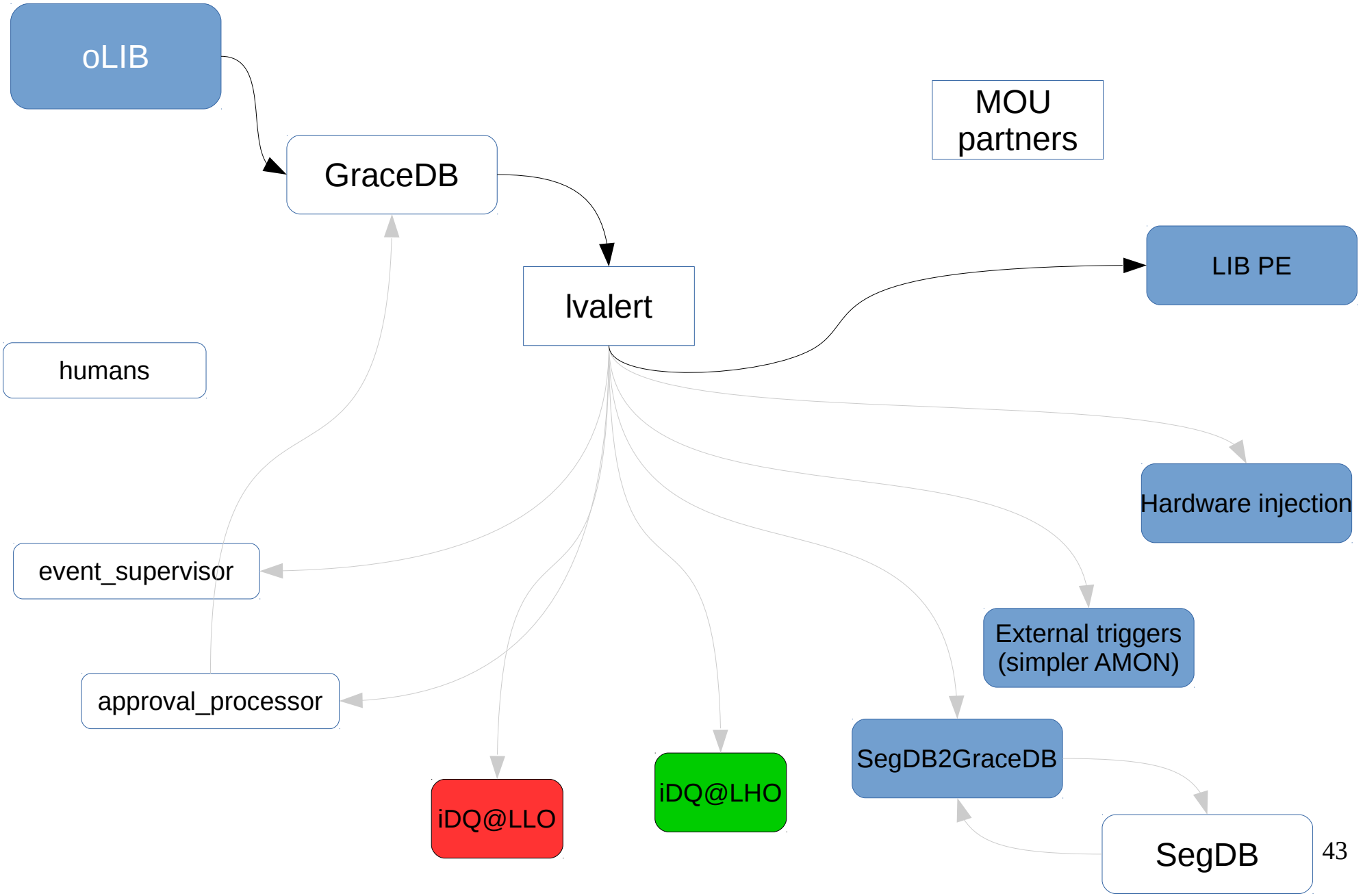

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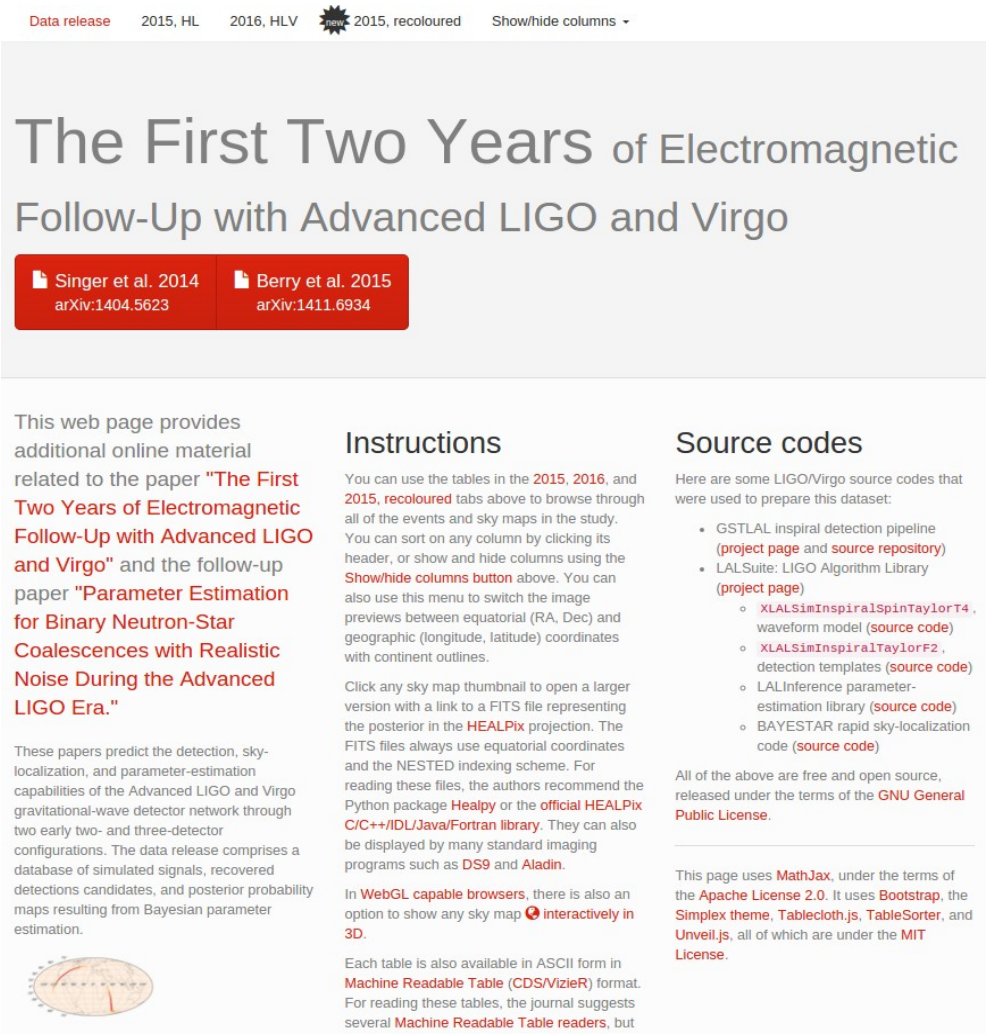
LIGO Open Science Center (LOSC) provides instructions on how to access and manipulate archival LIGO data. A variety of formats are provided as well data quality information.

S5 data : 2005 - 2007
S6 data : 2009 - 2010

BNS F2Y OpenData

A large-scale MDC study of detectability of BNS signals in both Gaussian and re-colored noise. Provides estimates on the expected detection rate as well as a large catalog of Bayestar and LALInference localizations.



Public Data

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S5 data : 2005 - 2007
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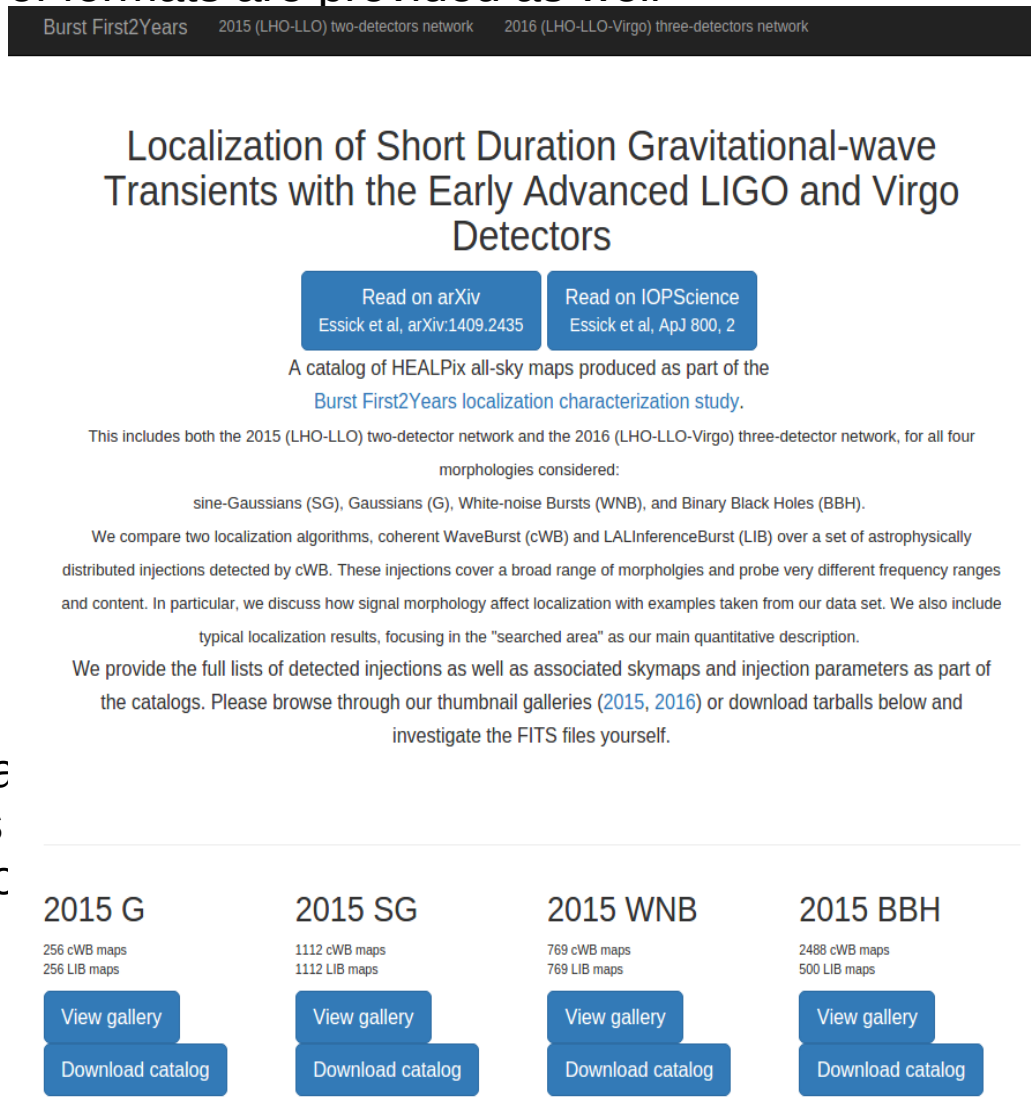
BNS F2Y OpenData : arXiv:1404.5623
A large-scale MDC study of detectability of BNS signals in both Gaussian and re-colored noise. Provides estimates on the expected detection rate as well as a large catalog of Bayestar and LALInference localizations.

Burst F2Y OpenData arXiv:1409.2435
A large-scale MDC study of burst localiza in Gaussian noise. Makes no predictions for detection rate. Provides a large catalc of cWB and LIB localizations.



Lessons learned during O1

Latencies associated with pipelines and follow-up processes.

What needs to be monitored.

What can be automated.

Glitch background and how it affects searches.

Planned improvements for O2+

Update/improve approval_processor → send alerts without human verification?

Update/improve event_supervisor (mostly internal)

Improve DQ, it's “verbosity” and it's application to searches
(reinstate streaming iDQ to CIT, GraceDB reports, etc)

Improve automated skymap comparison to reject glitches

Misc stuff, else? generic “improve pipelines”

references/pointers