Time Domain Computing: Solving the Follow-up Crisis

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Assumptions

- The time-domain events of interest cannot be scheduled (e.g. the behavior is not periodic).
- Transient finders like LSST will generate so many events that follow-up systems will be overwhelmed----triage will be essential.
- Instruments intercommunicate in real-time.
- Heterogeneous instrumentation and capabilities.
- Information and knowledge is freely shared between systems.
- Network employs robotic instruments with real-time data analysis.

How do Robotic Instruments handle Time Domain Events now?

- The second grade soccer problem…

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Need to fuse two different classes of Distributed Artificial Intelligence Research

Distributed Problem Solving

- Solves problems by dividing among distributed “nodes”.
- Nodes are centrally designed and controlled as slaves.

Multi-Agent Systems

- Coordinates autonomous intelligent agents.
- No global control
- Agents are self-motivated and act only according to their success criteria.
- Competition between agents.

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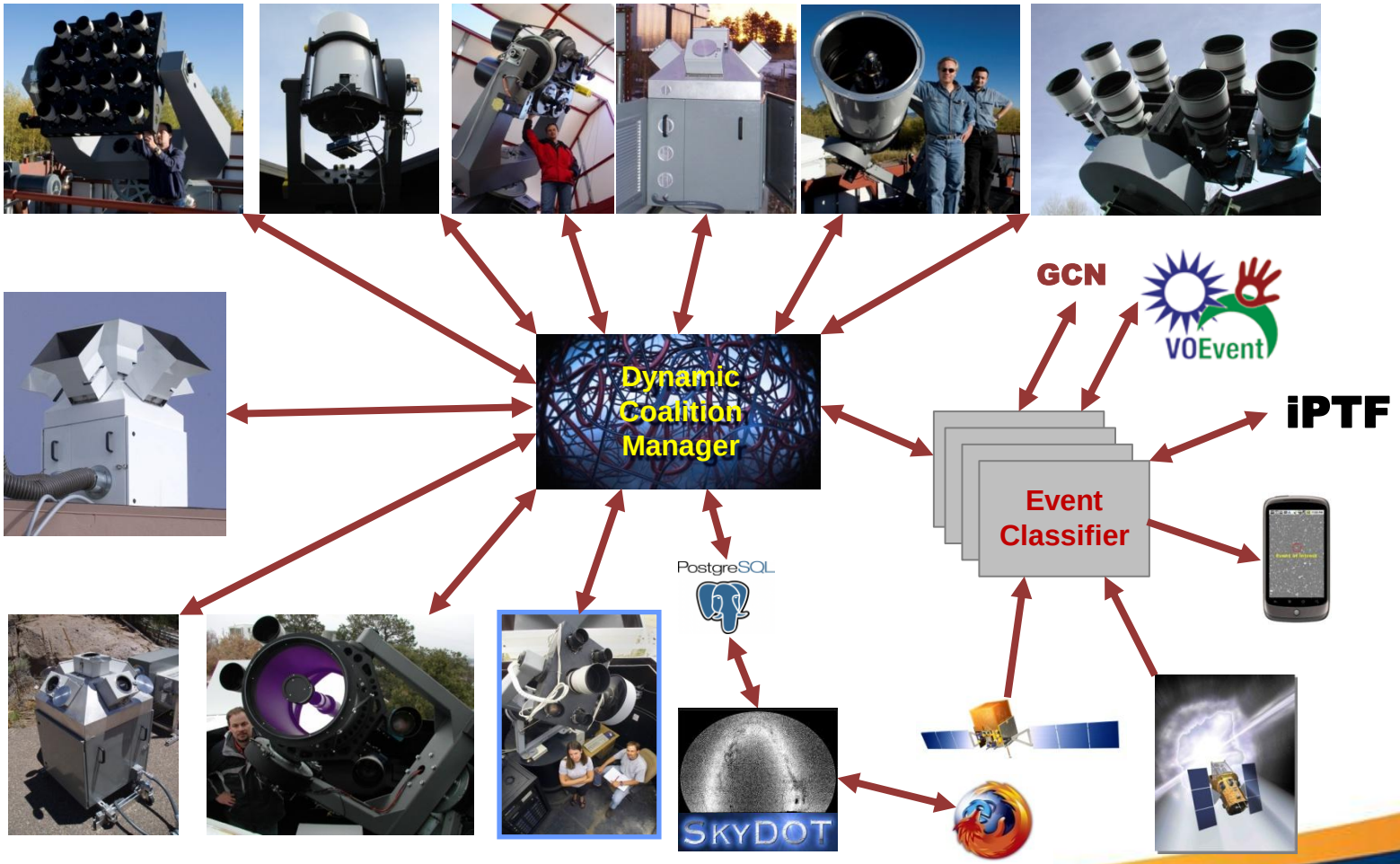
Our solution: A Dynamic Coalition Architecture (DCA) that employs Case-Based Reasoning.



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Dynamic Coalition Architecture (DCA)

- Each Transient is treated as a potential dynamic coalition.
- Each instrument has a software Agent that represents it.
- Approach uses real-time negotiation of Agents to optimize scientific return by forming response coalitions.
- Broker assigns an initiating Agent/moderator. This moderator then collects members, ranks them, assigns roles, and manages the coalition.

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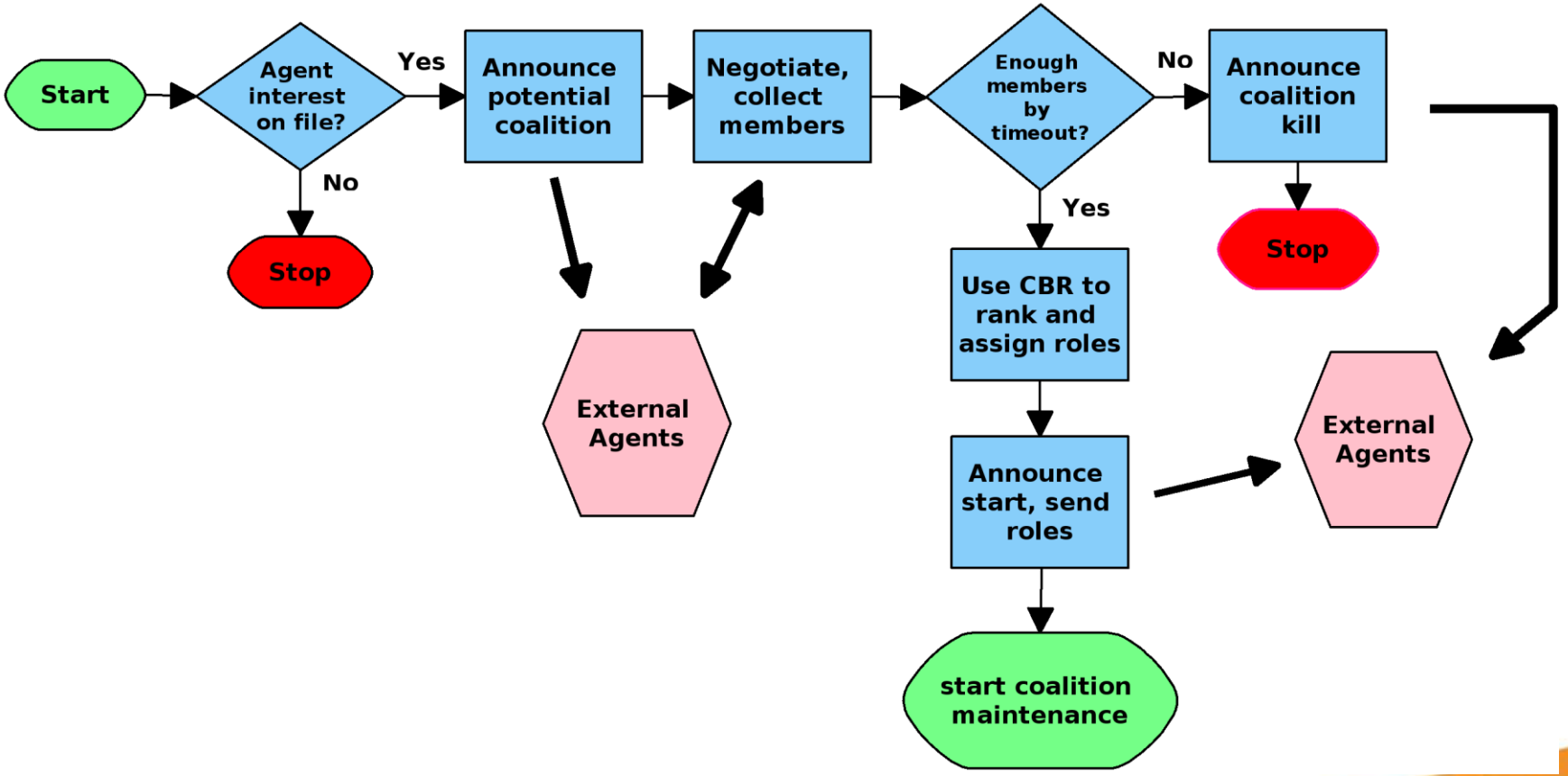
Dynamic Coalition Initiation



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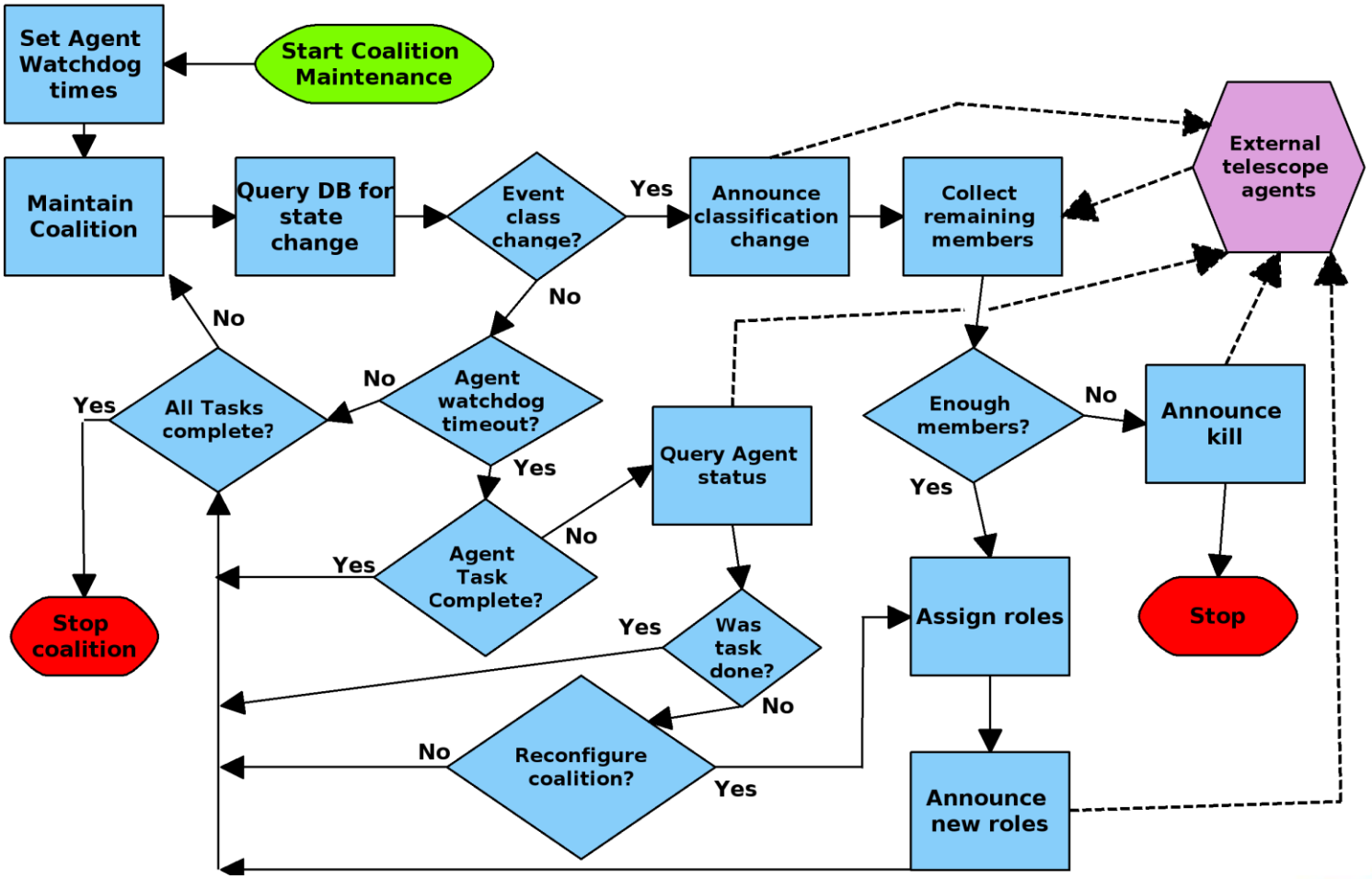
Case-Based Reasoning with Learning

A Case includes:

- A transient description and its current state (e.g. fresh Swift localized GRB, LIGO Event, SN Ia declining, fast radio transient,…, unknown bright optical transient, etc.)
- A solution description: what measurements need to be made, when they need to be made.
- A measurement of the quality of the solution outcome. *This allows human subject matter experts to improve the solution and allow the system to learn.*

Dynamic Coalition Management



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Inviting and Ranking Coalition Members for tasks

Agent Profile

- Name
- Geographic location
- Communication address
- Capabilities, potential configuration
- Real-time reconfiguration capability
- Trustworthiness---previous behavior, quality of results
- Not just telescopes, Agents could represent robots (or humans) mining an archive of historical information.

“Sophisticated” Telescope Agent Considerations

- Is the science associated with this coalition of interest?
- Do I have the sensitivity to make a observation of the new opportunity?
- How important is what I am doing now? And how long will it be before completion?
- How well does it match my “uniqueness” parameters?
- What is the highest impact observation that I can make right now?
- Individual agents can optimize their return using game theory techniques.

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Summary

- We are entering an exciting new era of time domain astronomy, where there will be an overwhelming number of transients found in real time.
- The nature of the transients will be diverse ranging from Multi-messenger events like Gravitational Wave events to electromagnetic transients over the full spectrum from gamma-rays to radio.
- Follow-up schemes employing an ecosystem of robotic telescopes would help maximize the scientific return.
- A multi-agent approach employing a Dynamic Coalition Architecture has many attractive aspects that would be useful for optimizing follow-up by the world's heterogeneous collection of instruments.
- A key piece that still needs to be developed is internationally standardized agent negotiation protocols and communication language.

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