An Experiment with Spectral Analysis Automation (SAA)

Walt Truszkowski — NASA Goddard Space Flight Center
Dr. Michael Rilee[1] — L-3 Communications GSI
Dr. Sidney Bailin — Knowledge Evolution, Inc.

[1] *Presenting*

NASA's Earth Science Technical Conference
Paper B8P1
24 June 2004

Michael.L.Rilee.1@gsfc.nasa.gov

M. Rilee, L-3 GSI, NASA/GSFC Spectral Analysis Automation, ESTC, 23 June 2004.

SAA Agent-group

Walt Truszkowski, *Lead*	NASA/GSFC
Tim McClanahan, *NEAR Data & Neural Nets*	
Dr. Sidney Bailin, *SAA Development*	Knowledge Evolution, Inc.
Dr. Pamela Clark, *NEAR* & Asteroid *Science*	L-3 Communications GSI
Dr. Michael Rilee, *Data assessment & filters*	
Jay Karlin, *SAA adaptivity & architecture*	Viable Systems, Inc.
Dr. Victoria Yoon, *Agent reuse & human interfaces*	UMBC

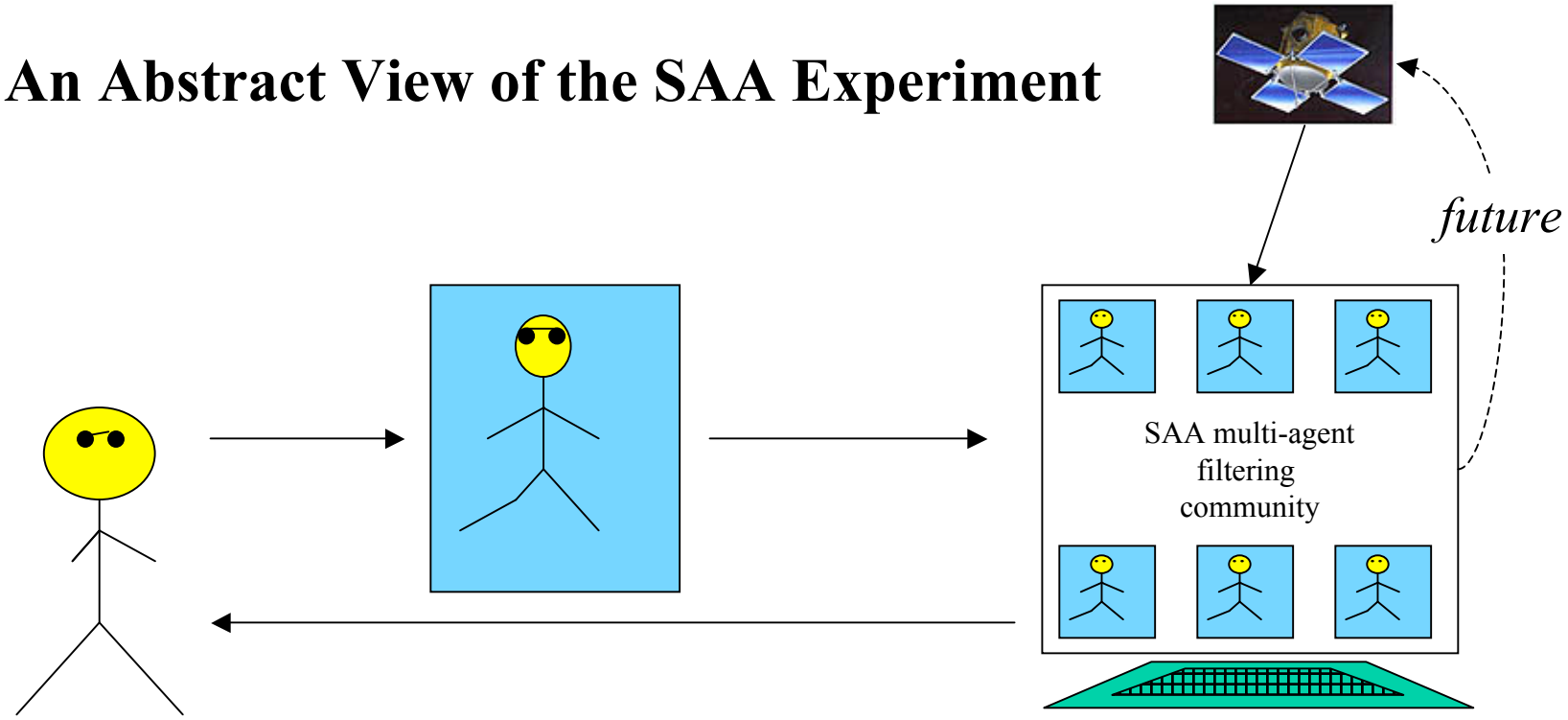
SAA Goals

- to assist scientists by filtering (assessing) spectral data

- to contribute to on-board processing of science data

- to extend the use of agent technology
    - science data processing
    - progressive autonomy of systems

An Abstract View of the SAA Experiment



Principal investigator “embeds” filtering goal in agent which migrates to the SAA filtering community. SAA filters data and sends selected spectra to scientist.

Spectral Analysis Automation

- **Motivation**
- **Scientific framework**
- **SAA Prototype**
- **Conclusions**

- **ANTS**
- **Spectrometry**
- **Multiple goals**
- **Limited means**
- **Progressive Autonomy**

Mission Drivers for Autonomous Agent Capabilities

- Robotic infrastructure for Exploration & Support
  - Multiple remote elements
- Communication latency and bandwidth
  - Remote systems, high data production rates
- Hazardous environments
  - Mars, Lunar highlands, Asteroids, deep space
- Limited human presence
  - Maximize use of human presence, minimize distractions
  - Complement human capabilities

The road to
Autonomous Agents for Science & Exploration

- Multiple conflicting goals
  - Classify percepts, prioritize, plan, and act
- For current tools, human-in-the-loop is the norm
  - Spacecraft operations, planning, data analysis
- Can we
  - increase researchers' productivity?
  - develop a robotic research assistant?
  - make it an autonomous remote system?
- Need to develop
  - a perception capability
  - an approximation to judgment

Spectral Analysis Automation

- Motivation
- **Scientific framework**
- SAA Prototype
- Conclusions

- ANTS
- **Spectrometry**
- Multiple goals
- Limited means
- Progressive Autonomy

Eros Questions

Near Earth Asteroid Rendezvous

Psyche crater

Important questions for every asteroid:

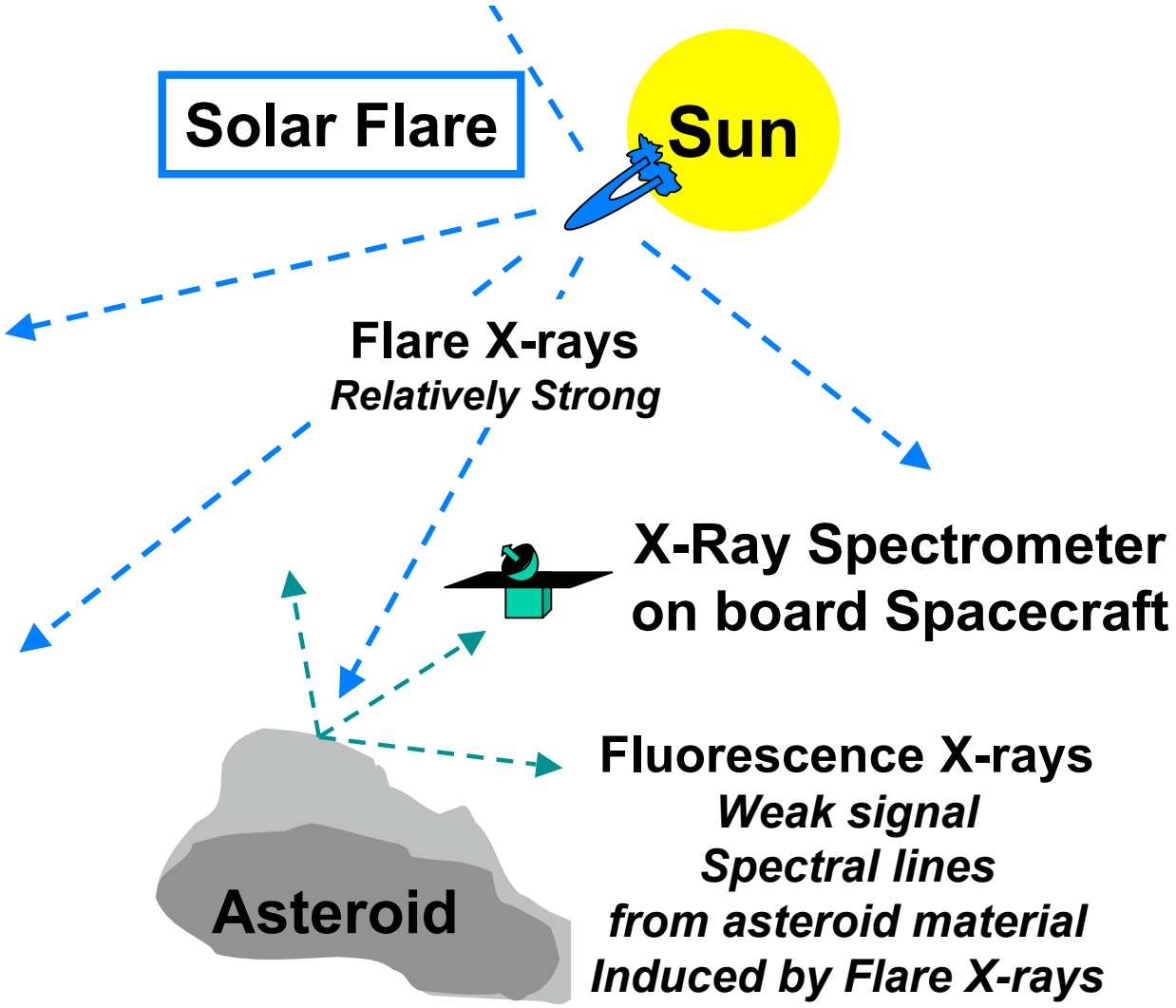
To what family of Asteroids does Eros belong?

What meteors on Earth resemble or may have come from Eros?

What is the composition of Eros?

Spectrometry provides important constraints & information.

X-ray Fluorescence Spectrometry
Spacecraft Remote Sensing

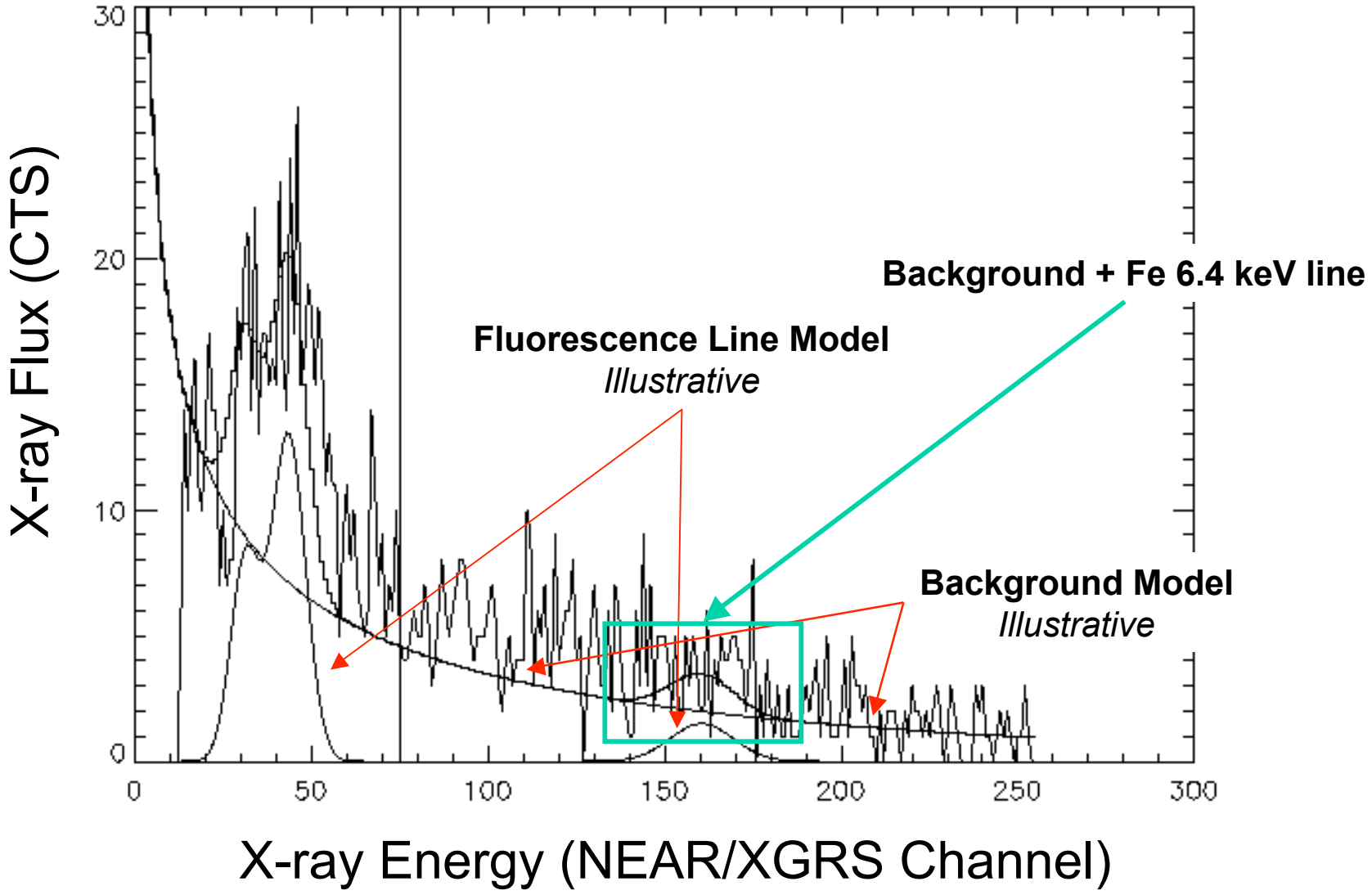


SAA currently supports two filters.

- **Artificial Neural Net**
- Trained to recognize XRF lines

- **Bayesian Likelihood**
- Odds of a signal vs. noise alone

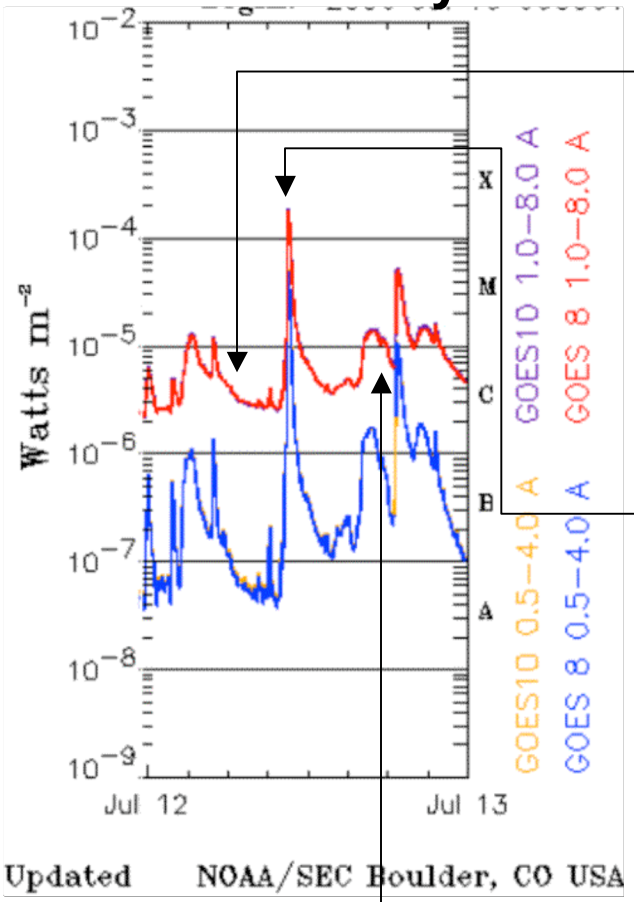
NEAR XGRS X-ray Fluorescence Spectrometry

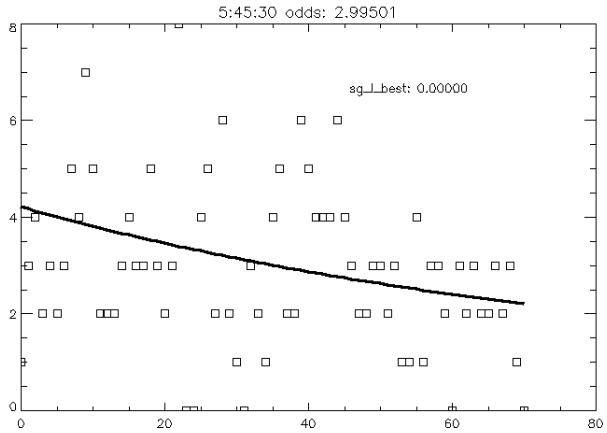


M. Rilee, L-3 GSI, NASA/GSFC Spectral Analysis Automation, ESTC, 23 June 2004.

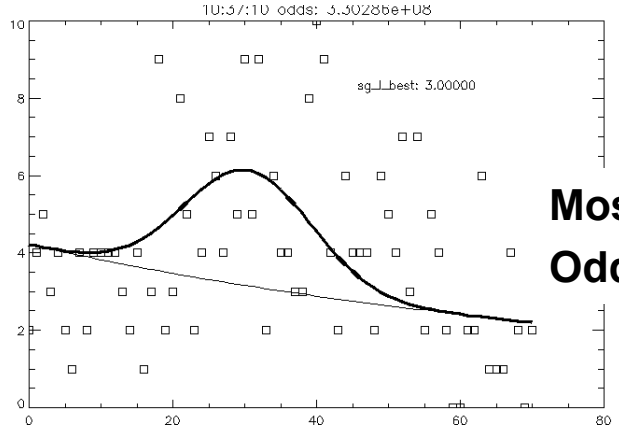
NEAR XGRS Data & "Best Model"

GOES Soft X-ray Flux



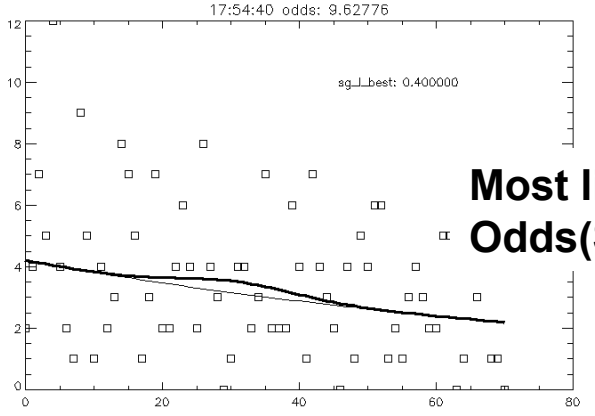


Most likely S/N ~ 0
Odds(S>0) ~ 3:1



X-class flare

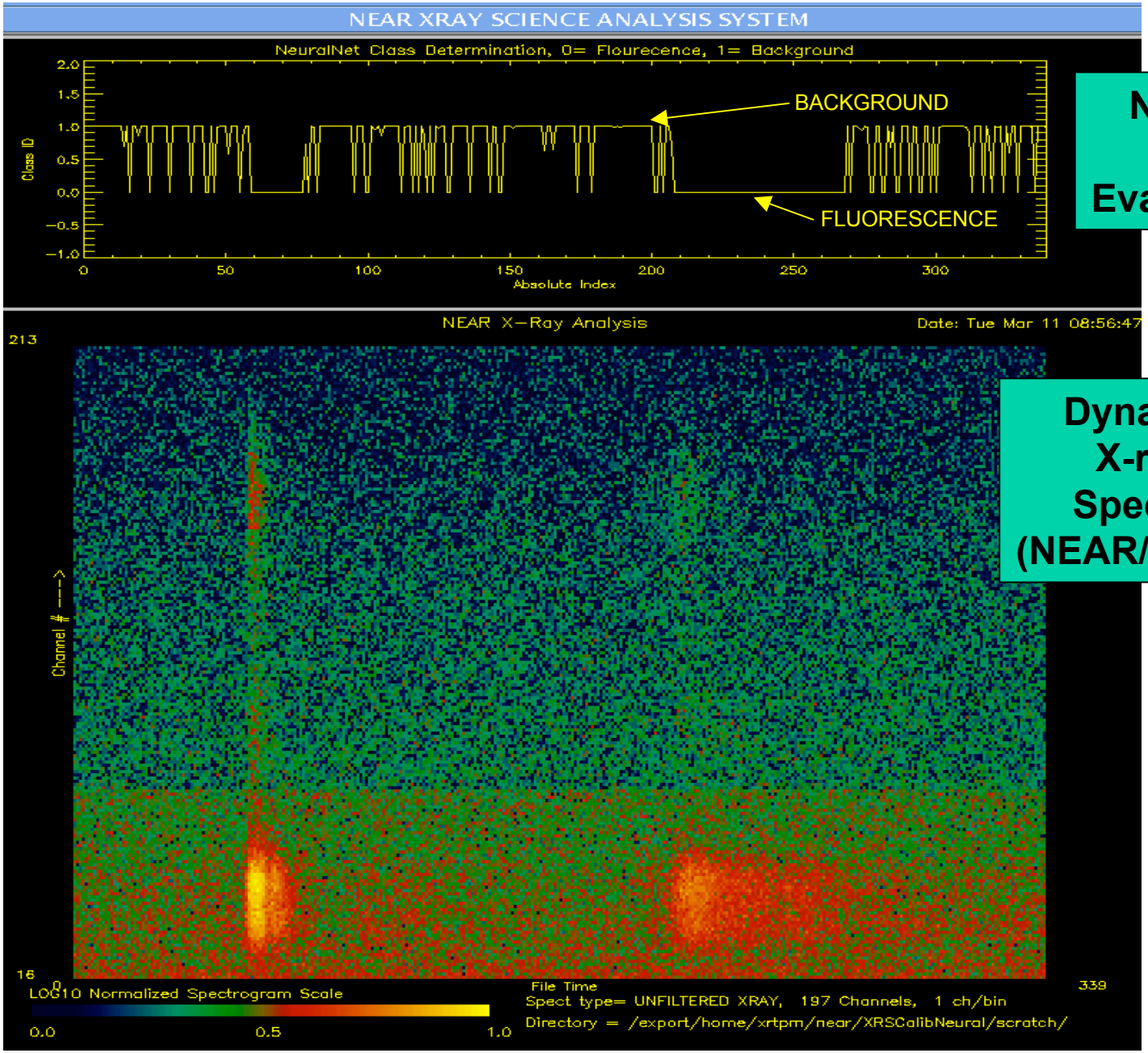
Most likely S/N ~ 1 – 2
Odds(S>0) ~ 3×10^8:1



M-class flare

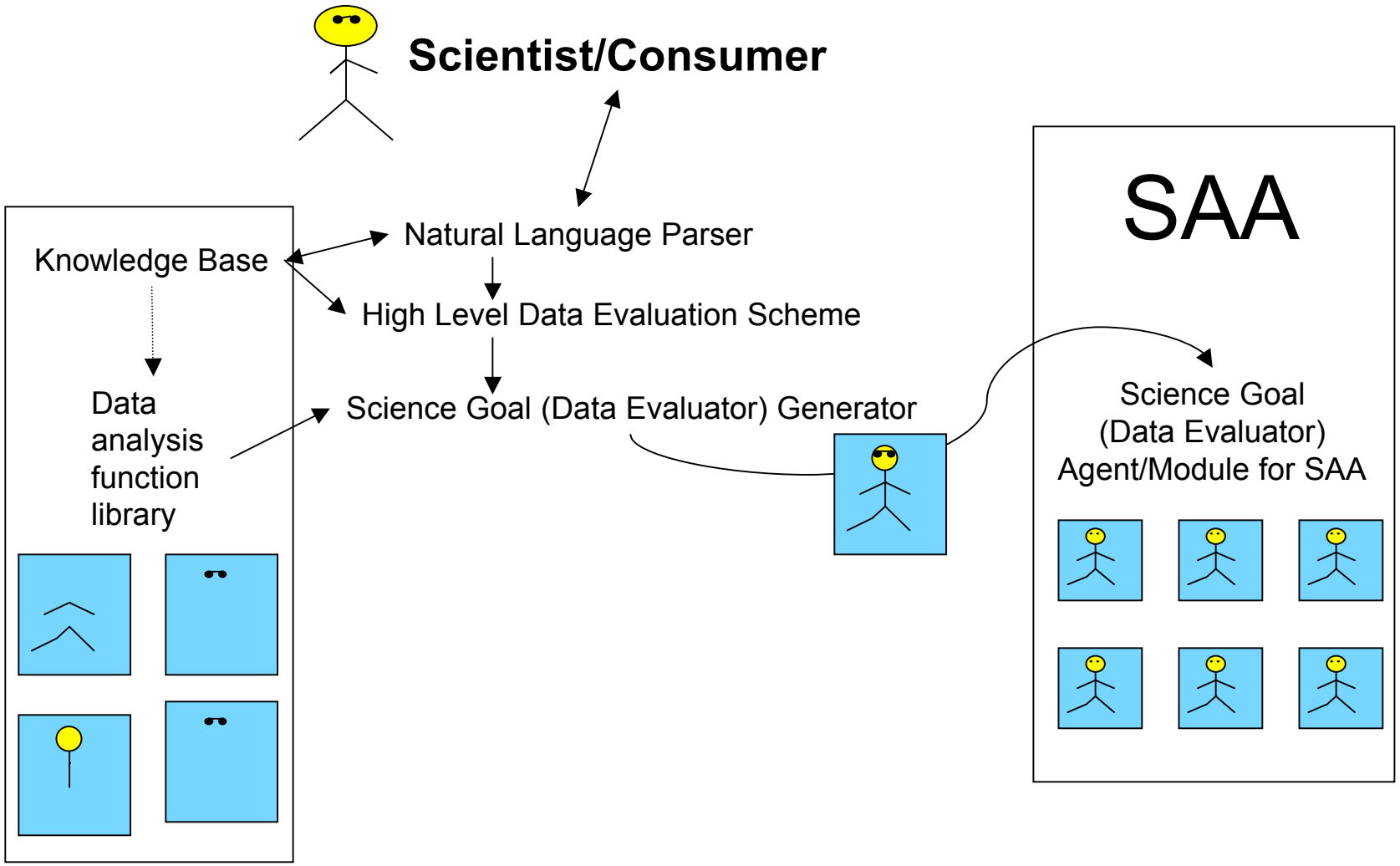
Most likely S/N ~ 1/10
Odds(S>0) ~ 10:1

S: Signal; N: Noise; S/N: Signal-to-noise ratio.



A Neural Net Filter for Spectral Data

Conceptual Structure of SAA Science Goal Generation

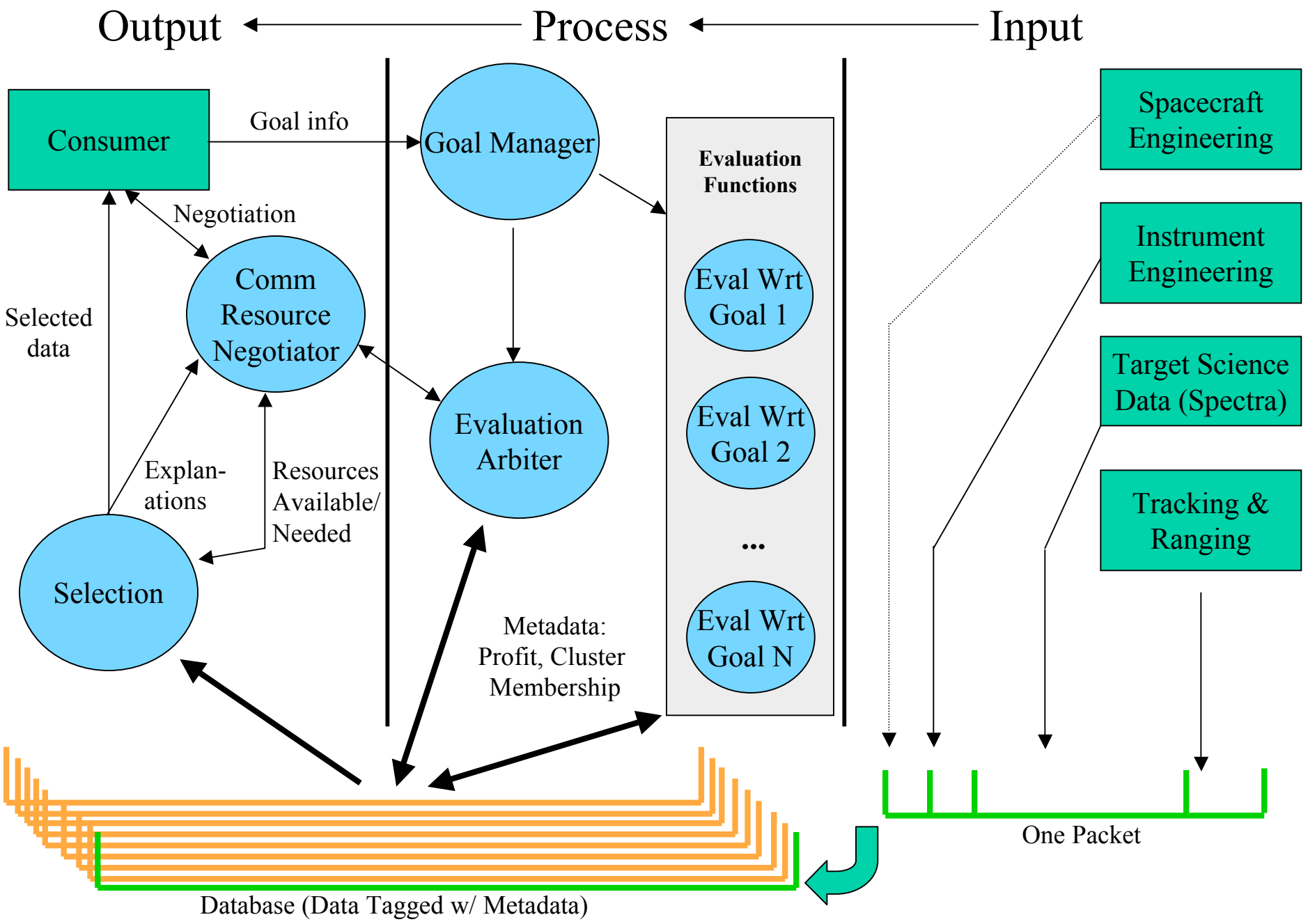


Spectral Analysis Automation

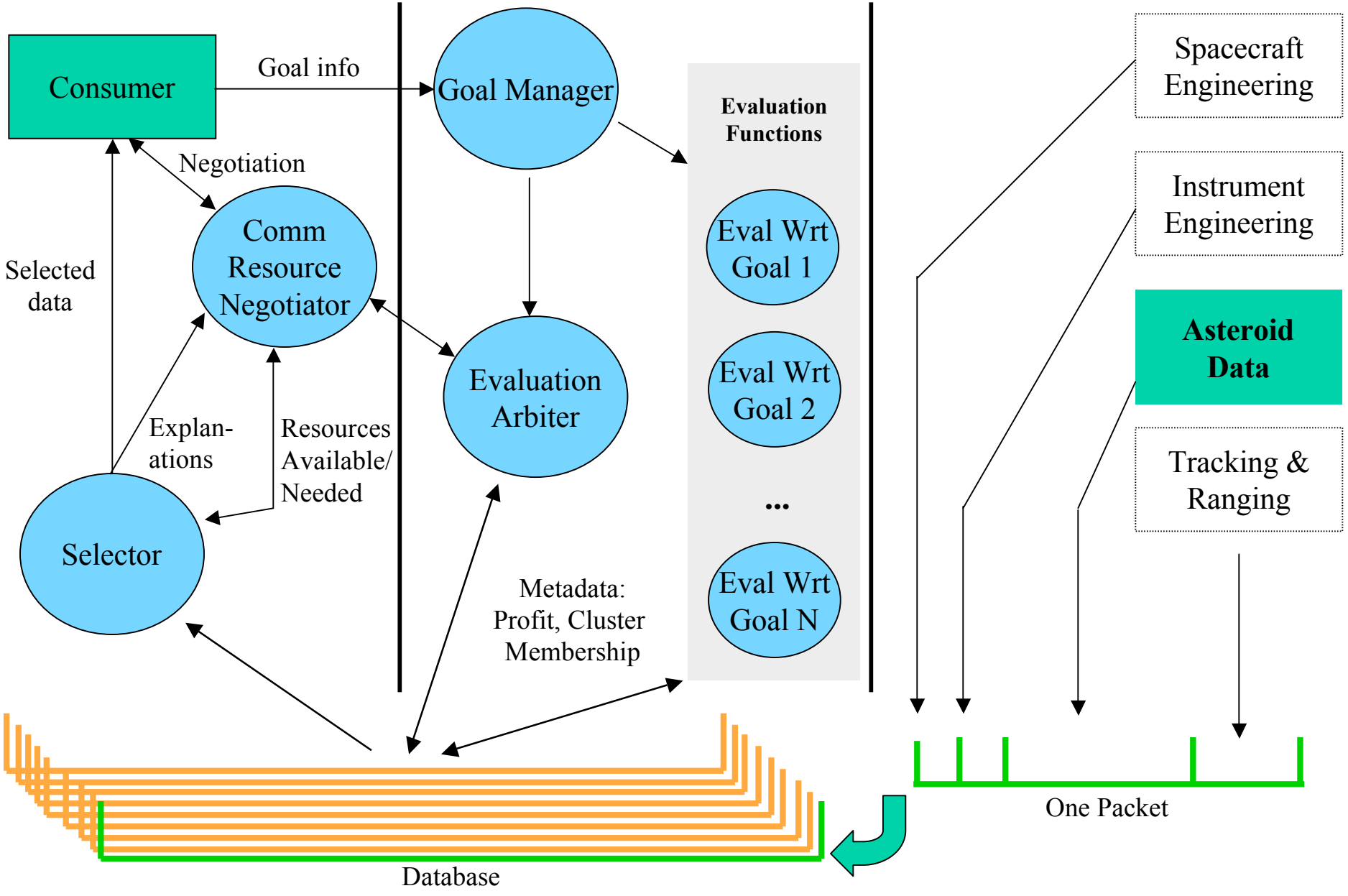
- Motivation
- Scientific framework
- **SAA Prototype**
- Conclusions

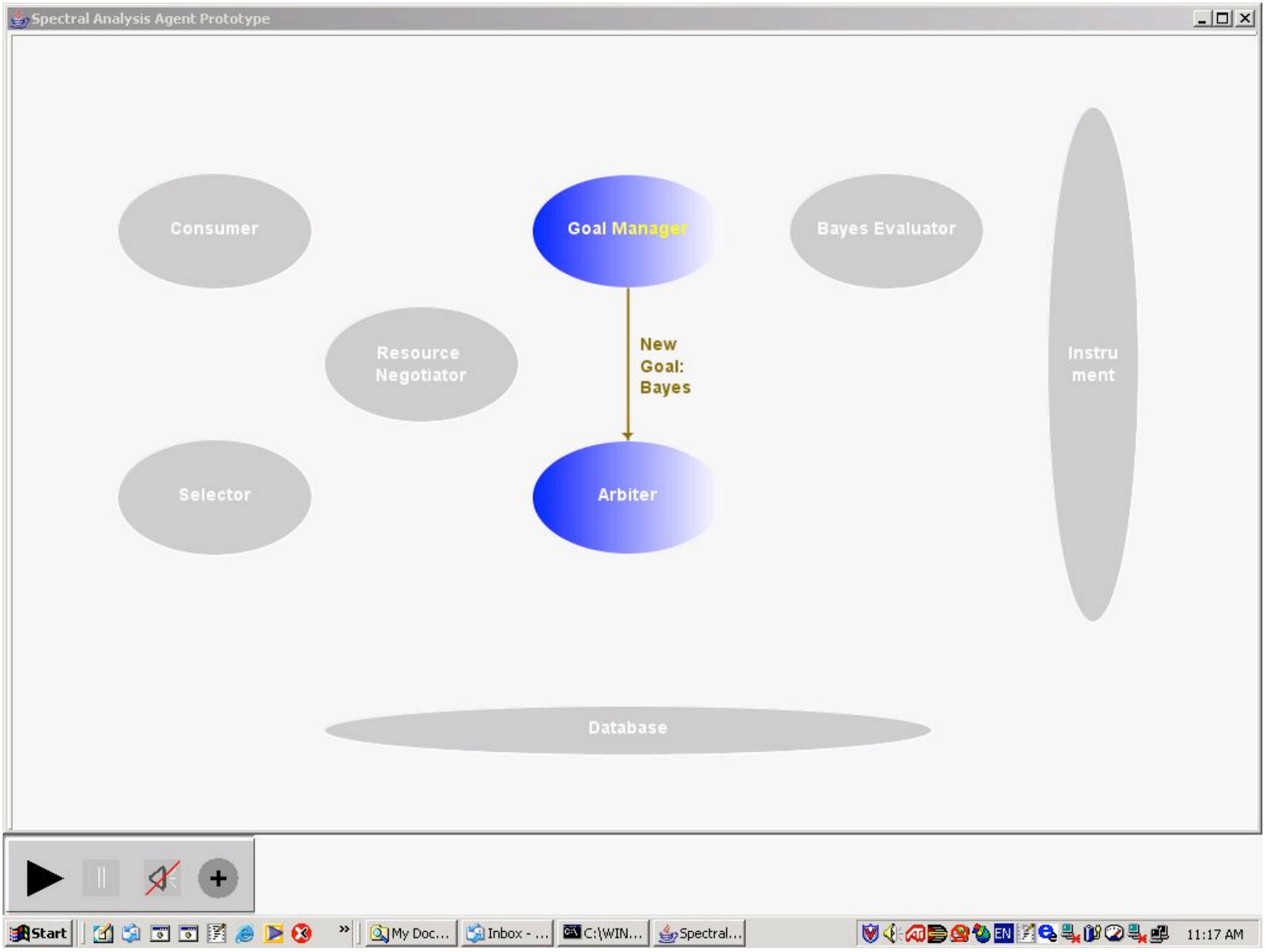
- ANTS
- Spectrometry
- **Multiple goals**
- **Limited means**
- Progressive Autonomy

Spectral Analysis Automation / Data Filtering System Infrastructure



Filtering remote sensing data from the asteroid belt prior to downloading it to Earth




Spectral Analysis Agent Prototype
Consumer
Goal Manager
Bayes Evaluator
Instru
ment
Resource
Negotiator
New
Goal:
Bayes
Selector
Arbiter
Database
Start
My Doc...
Inbox - ...
C:\WIN...
Spectral...
11:17 AM

Spectral Analysis Automation

- Motivation
- Scientific framework
- SAA Prototype
- **Conclusions**

- ANTS
- Spectrometry
- Multiple goals
- Limited means
- **Progressive Autonomy**

Progressive autonomy

SAA -

add agents to the system
new capabilities
new priorities
new goals

The system can become more adaptive and more autonomous.

Parts of the system may be remotely deployed.

The architecture covers distribution.

Current Tasks

- **Filling out the evaluation support component library**
  - Support scientists' evaluation methods
  - Use more of structure of the data
- **Role of context in evaluation**
  - Importance of a datum in the context of the mission
  - How does a datum change the context?
- **Arbitrating between different evaluations**
  - Consensus mechanism to determine importance
- **Performance feedback for adaptability (learning)**
  - Consumer based
  - Machine based

Conclusion

- **SAA is a multi-agent system that examines science data**
  - Science users (Consumers) formulate goals
    - Goals are used to construct evaluation agents (Evaluators)
    - Evaluation agents are transmitted to the SAA system
  - Different goals are pushed forward by different agents
    - An Arbiter forms a single evaluation from the many
  - SAA Agents are distributed
    - many local to the data gathering platform itself
  - SAA Prototype operates in a data mining mode on NEAR data
  - Progressive autonomy allows smaller steps to be taken

The SAA is an attempt to build the framework for a feedback loop that will enable Scientists to build confidence in autonomous science operations.

Architectural structure of an Agent