Cloud Services for Optimization Modeling Software

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Abstract

Optimization modeling systems first became available online soon after the establishment of the NEOS Server almost 20 years ago. This presentation describes the evolution of NEOS and other options in what came to be known as cloud computing, with emphasis on the modeling aspects of optimization. In comparison to solver services that compute and return optimal solutions, cloud services for building optimization models and reporting results have proved especially challenging to design and deliver. A collaboration between local clients and cloud servers may turn out to provide the best environment for model development.

Cloud Services / *Software as a Service*

Client side

- Computing device owned by the user's organization
- Client application run by the user on local processors

Server side

- Workstation owned by a computing provider
- Service running automatically on remote processors

Not considered here . . .

- User logged in to the remote computer
- Server side managed by the user's organization

Optimization

No one way to optimize

- Numerous problem classes
- Alternative methods for each class
- Competing free and commercial *solvers*

Models built to order

- Competing *modeling systems*
- Each system supports multiple solvers
- Many solvers work with multiple systems

A tangle of software

- Market not dominated by comprehensive packages
  - compare statistics, simulation
- Performance varies greatly

Optimization as a Service

Two main examples . . .

NEOS Server

- Free cloud service for optimization since 1996
- Originated many ideas still relevant today

Gurobi Instant Cloud

- Commercial cloud service for optimization
- Most extensive / instructive recent offering

. . . both offer modeling language interfaces

NEOS Server www.neos-server.org

Network Enabled Optimization System

- Originated 1995 at Argonne National Laboratory
  - U.S. Department of Energy
- Since 2011 at Wisconsin Institutes for Discovery
  - University of Wisconsin, Madison

Free access to optimization software

- Over 40 solvers
- Several optimization modeling languages

Origins

Meeting over lunch in spring 1995

- Argonne representatives (?)
  - Rick Stevens, Jorge Moré, Steven Wright
- Northwestern representatives (?)
  - Jorge Nocedal, Bob Fourer

Plan for a new project

- Automate the use of optimization libraries
- Promote "optimization as an internet resource"
- Take advantage of the "new" World Wide Web

NEOS Server

Architecture

Distributed workstations

- Offer varied inputs & solvers
- Process submissions on demand
- Contributed by varied organizations

Central scheduler

- Receives and queues submissions
- Sends submissions to appropriate workstations
- Returns results

Minimal hands-on management

- *Distributed:* Install NEOS software on workstations
- *Central:* Update server database of workstation locations and abilities

NEOS Server

Original Facilities

Local submission clients

- Email
- Website
- NEOS submission tool

Problem description formats

- Linear: MPS and other solver files
- Nonlinear: Fortran or C programs
  - automatic differentiation of programs

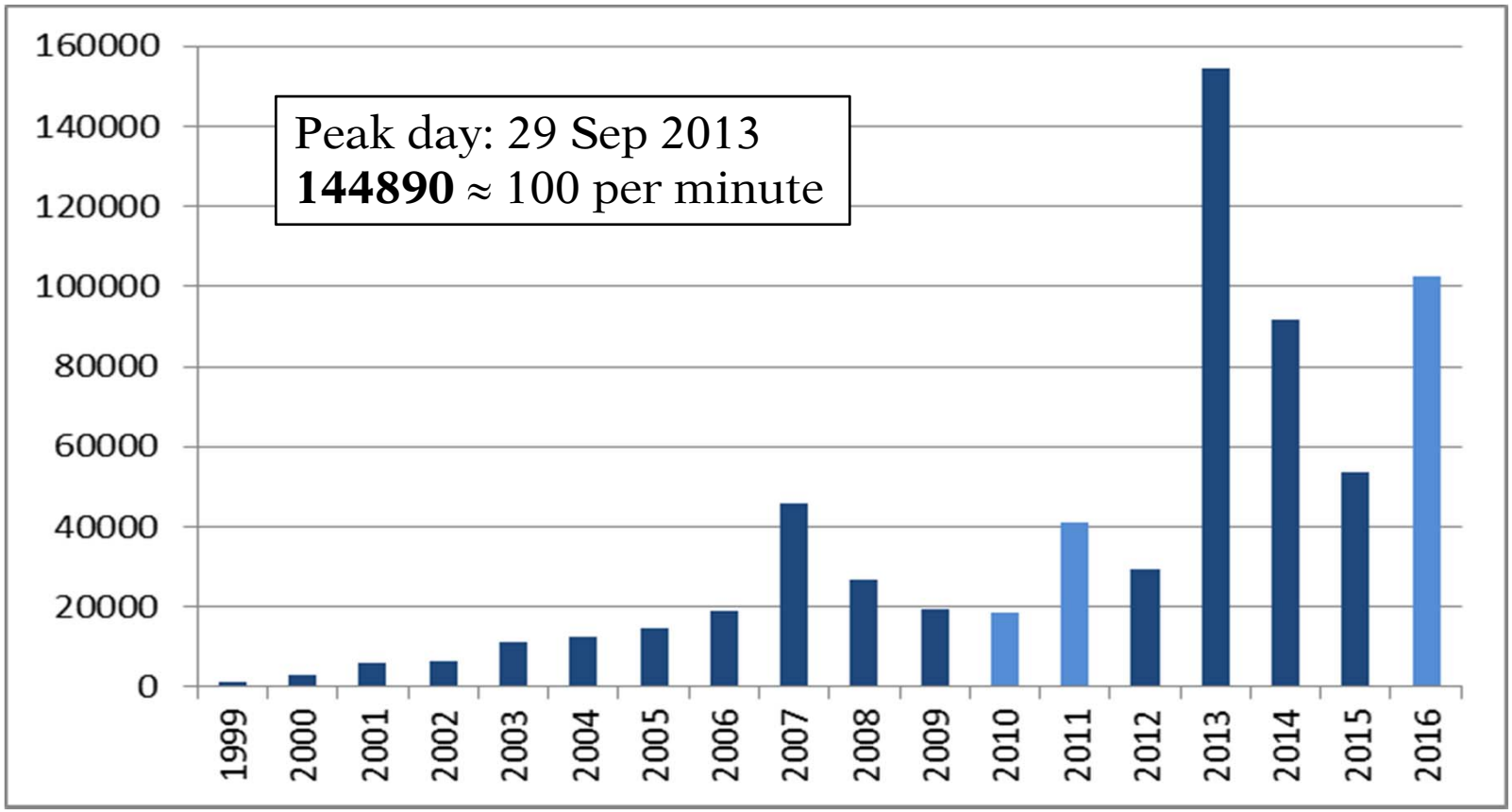
W. Gropp and J.J. Moré, 1997. **Optimization Environments and the NEOS Server**. *Approximation Theory and Optimization,* M. D. Buhmann and A. Iserles, eds., Cambridge University Press, 167-182.

J. Czyzyk, M.P. Mesnier and J.J. Moré, 1998. **The NEOS Server**. *IEEE Journal on Computational Science and Engineering* **5**(3), 68-75.

NEOS Server

Impact: Total Submissions

Monthly rates since 1999

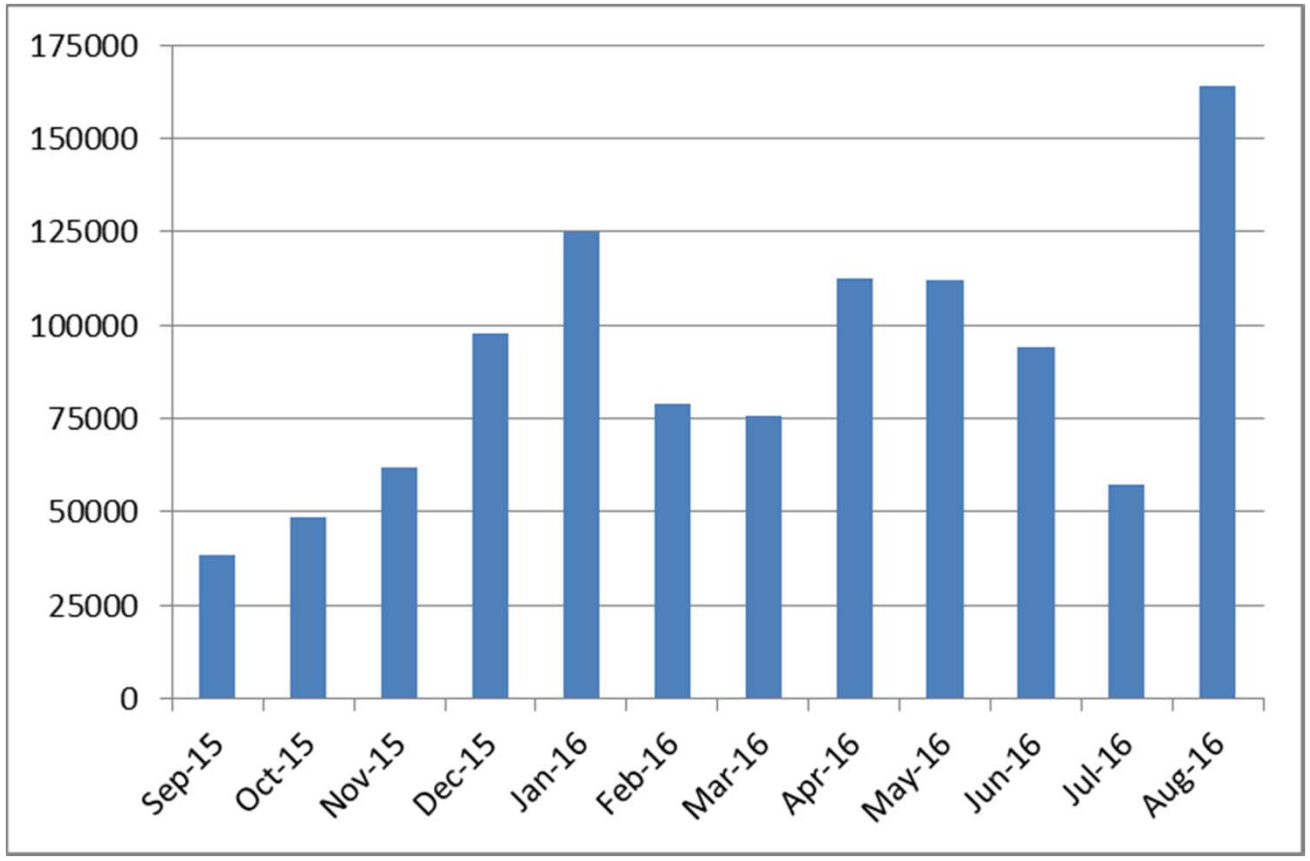


45000/month ≈ one per minute

NEOS Server

Impact: Recent Submissions

Monthly rates for past year



45000/month ≈ one per minute

NEOS Server

Assessment

Strengths

- Free
- Choice of solvers
  - Every popular solver available
- Easy to use
  - No account setup
  - No advance scheduling

Weaknesses

- Stand-alone focus: submission of "solve jobs"
- Non-profit management
  - Limited support & development
  - No guarantee of confidentiality
  - No guarantee of performance

Recent Enhancements

More flexible workstation infrastructure

- Based on HTCondor "high-throughput computing"

Secure user authentication

- Option to register and sign in when submitting
- Potential advantages for registered clients
  - priority job execution
  - data security
  - "more services and better customized experiences"

Modeling Languages in NEOS

Modeling language inputs

- AMPL model, data, commands files
- GAMS model, options, gdx files

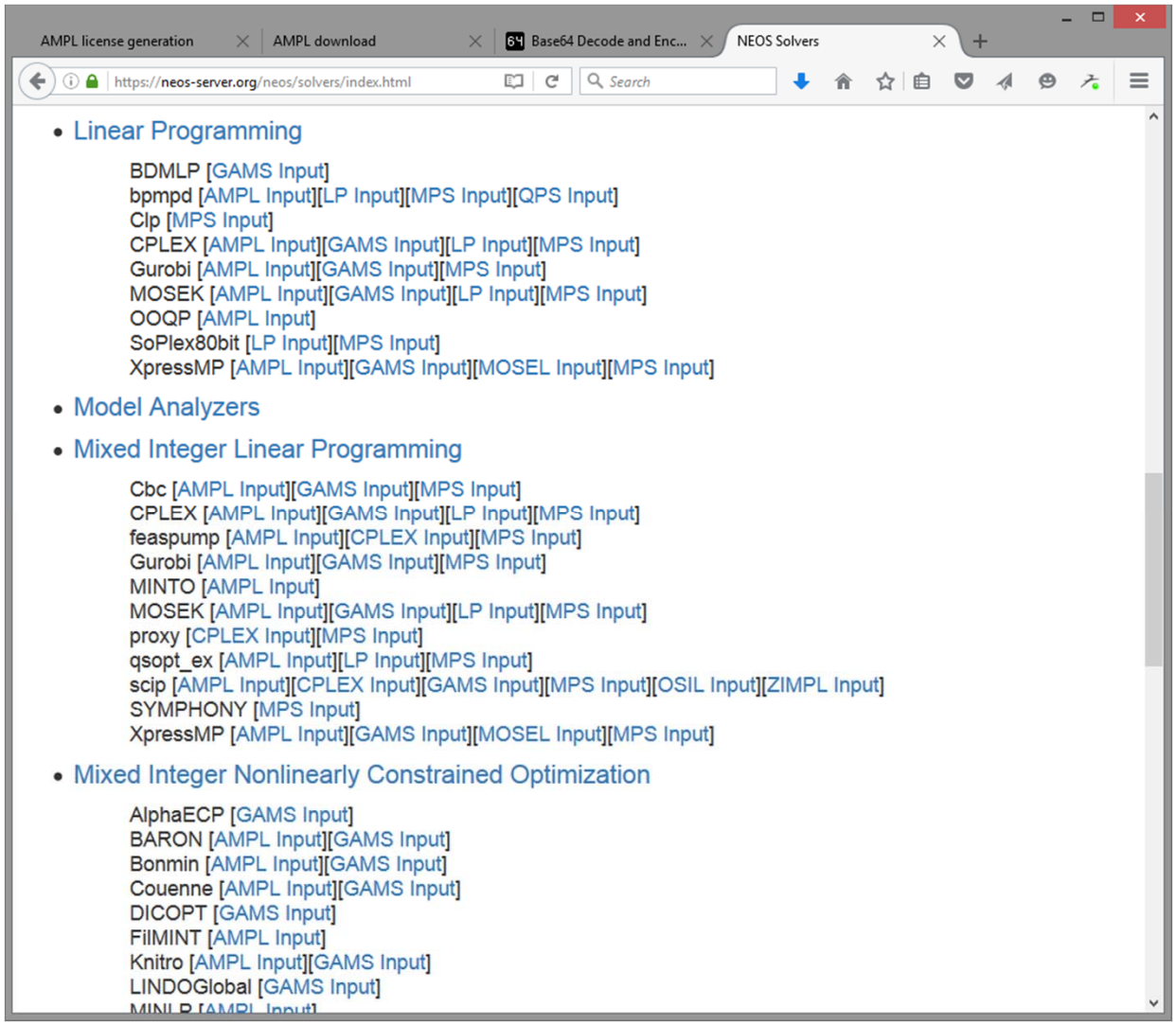
Modeling language operation

- User chooses a solver and a language
- NEOS scheduler finds a compatible workstation
- NEOS workstation invokes modeling language system with given inputs
- Modeling language system invokes solver

E.D. Dolan, R. Fourer, J.J. Moré and T.S. Munson,
Optimization on the NEOS Server. *SIAM News* **35:**6
(July/August 2002) 4, 8–9. www.siam.org/pdf/news/457.pdf

NEOS Server

Solver & Language Listing

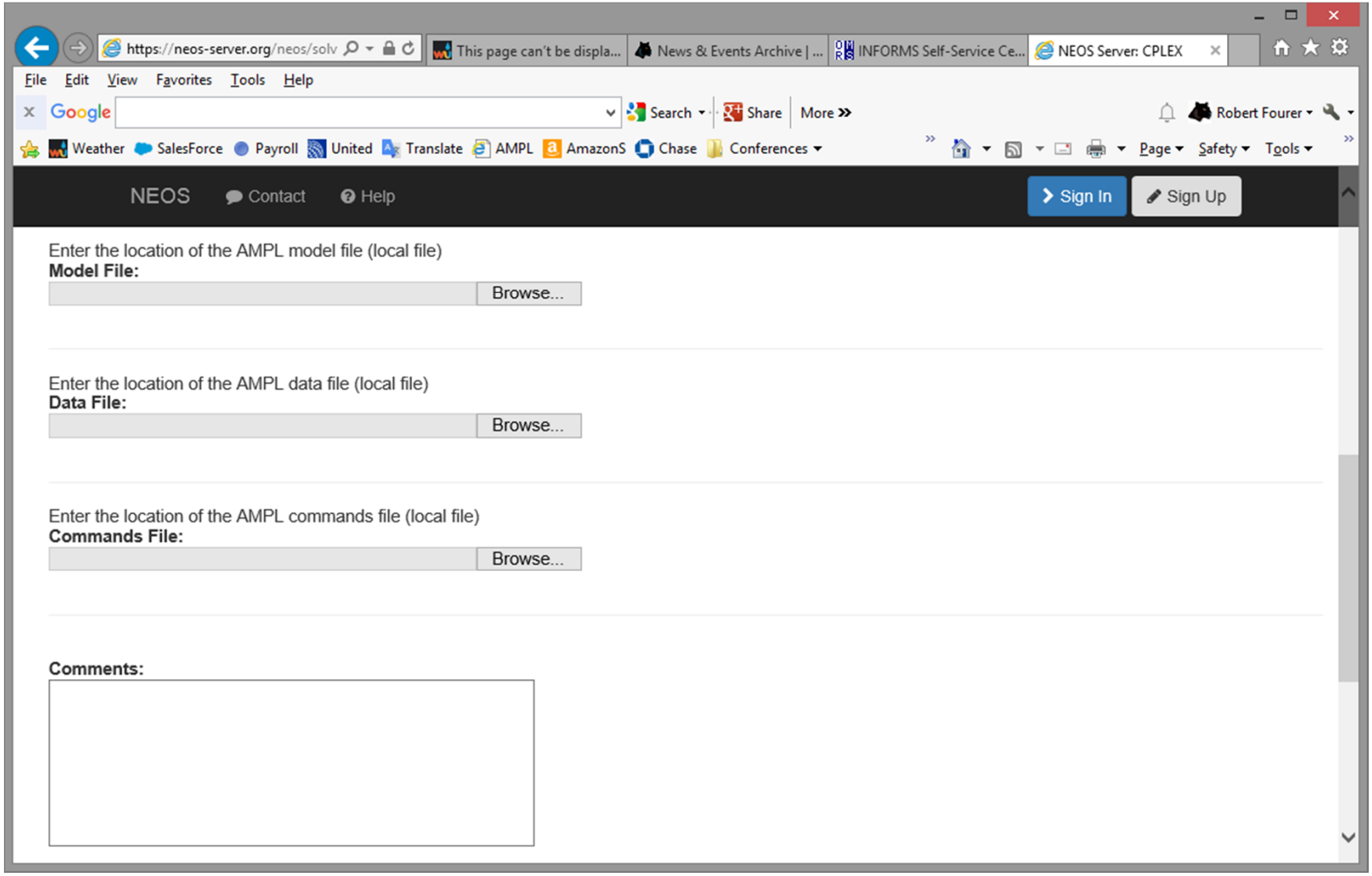


NEOS Server

AMPL Input Page

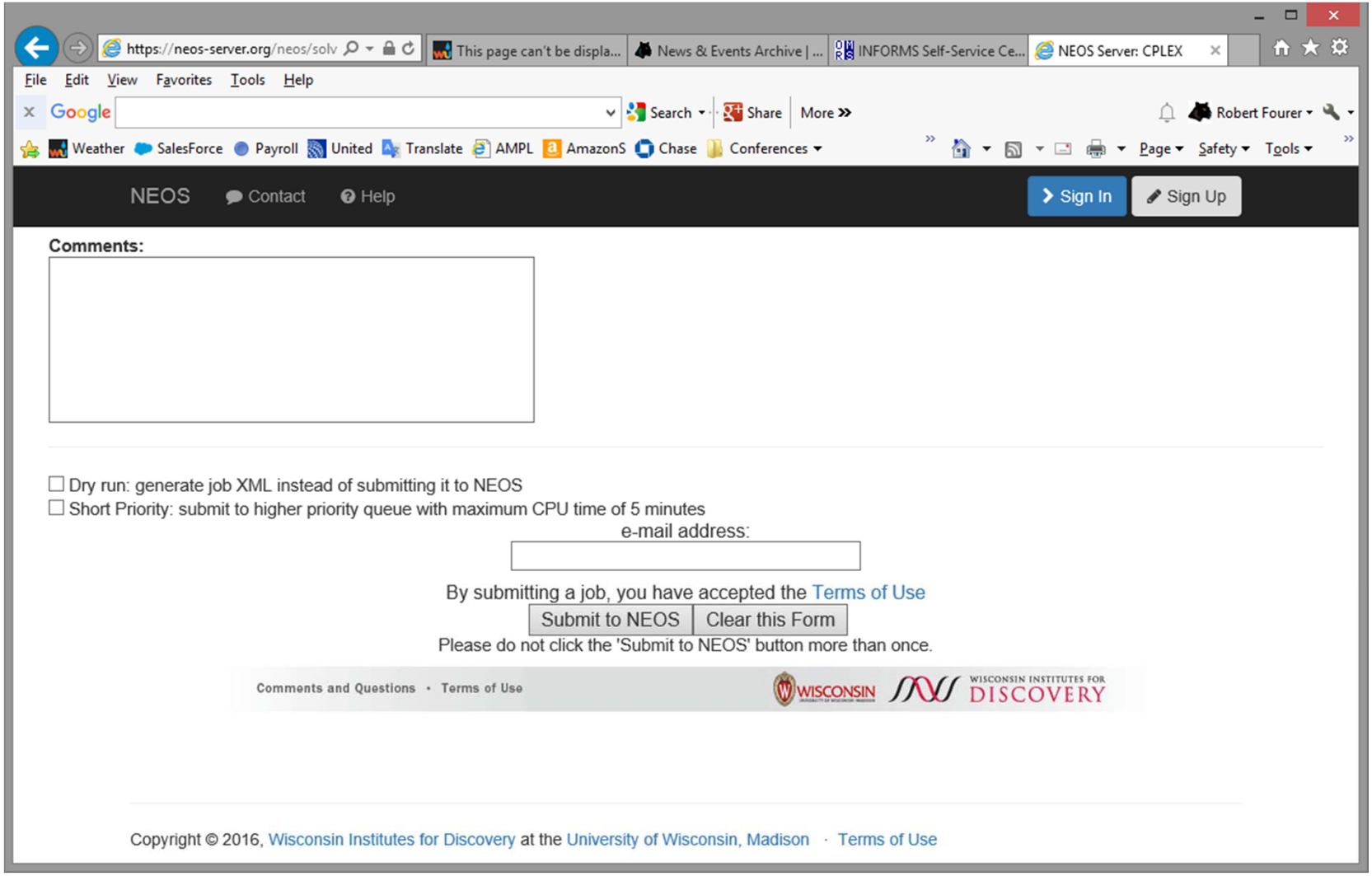
NEOS Server

AMPL Input Page



NEOS Server

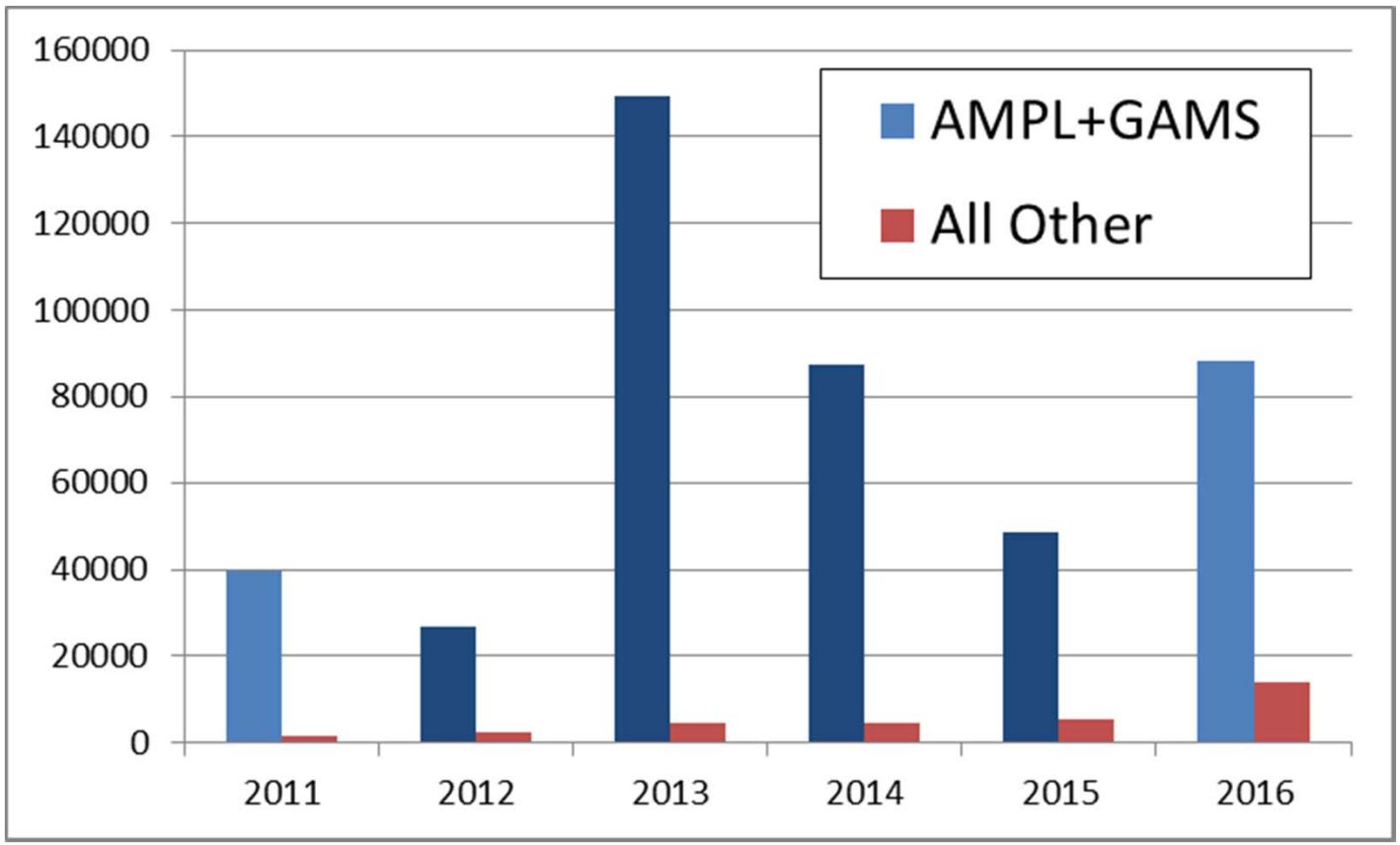
AMPL Input Page



NEOS Server

Impact: Modeling Languages

Monthly rates since 2011



Assessment: Modeling Languages

Strengths

- Easy to get started using NEOS
- High-level representation supporting >20 solvers

Weaknesses

- Lacks interactive features of modeling systems

APIs

Application programming interfaces

- Access NEOS from a local program

Implementations

- Version 1: XML-RPC remote procedure call
- Version 5: full Python API

Uses

- NEOS submission tool
- Custom-built applications
- **NEOS as a "solver" for modeling systems**

NEOS in Modeling Systems

New "solvers"

- Kestrel for AMPL
- Kestrel for GAMS

Familiar operation

- Choose Kestrel as the local "solver"
- Set an option to choose a real solver on NEOS
- Initiate a solve and wait for results

E.D. Dolan, R. Fourer, J.-P. Goux, T.S. Munson and J. Sarich, **Kestrel: An Interface from Optimization Modeling Systems to the NEOS Server.** *INFORMS Journal on Computing* **20** (2008) 525–538. dx.doi.org/10.1287/ijoc.1080.0264

NEOS Server

AMPL Interactive Session

```
ampl: model sched1.mod;
ampl: data sched.dat;

ampl: let least_assign := 16;

ampl: option solver kestrel;
ampl: option kestrel_options 'solver=cplex';

ampl: solve;

Connecting to: neos-server.org:3332
Job 4679195 submitted to NEOS, password='JMNRQoTD'

Check the following URL for progress report :

http://neos-server.org/neos/cgi-bin/nph-neos-
solver.cgi?admin=results&jobnumber=4679195&pass=JMNRQoTD

Job 4679195 dispatched
password: JMNRQoTD

---------- Begin Solver Output -----------

Job submitted to NEOS HTCondor pool.
```

NEOS Server

AMPL Interactive Session

```
---------- Begin Solver Output -----------

Job submitted to NEOS HTCondor pool.

CPLEX 12.6.2.0: optimal integer solution; objective 265.9999999999943
135348 MIP simplex iterations
17430 branch-and-bound nodes

ampl: option omit_zero_rows 1, display_1col 0;

ampl: display Work;

Work [*] :=

  1 16    11 16    36 19    72 20    82 20   106 16   114 20   125 20
  3 16    29 16    66 17    79 19   104 19   112 16   121 16
;

ampl:
```

Kestrel Impact

Some success

- 2013 and 2014:
  Peaked at over 500,000 submissions
- 2015:
  Dropped to only about 30,000 submissions
- 2016:
  Up to over 90,000 submissions in first 8 months

Kestrel Assessment

Strengths

- Powerful local client for modeling
- NEOS facilities for solving

Weaknesses

- Limited support & development
- Not all NEOS solvers available
- Local solver software is strong competition . . .
  - Bundled with modeling languages
  - Free for trial use
  - Free for course and academic use

More Recently . . .

NEOS in Solver Studio

- Excel add-in using AMPL/GAMS models, NEOS solvers

Optimization Services

- Fully distributed, decentralized alternative to NEOS

IBM Decision Optimization on Cloud

- "DropSolve" service similar to NEOS
- "DOcplexcloud API" like NEOS API

Gurobi Cloud Services for Optimization

- Original Gurobi cloud
- **Gurobi compute service cloud**

Gurobi Cloud

www.gurobi.com/documentation/6.5/cloud-guide/

Client side

- Any version of Gurobi
- Licensed for front-end use only

Server side

- Gurobi compute server for MIP
  - Single-machine solves with one or multiple servers
  - Distributed MIP
  - Distributed concurrent MIP
  - Distributed tuning
- Amazon Web Services hosts

"Cloud computing technology is changing quickly. Please check these documents periodically to ensure you have the latest instructions for the Gurobi Cloud."

Gurobi Cloud for AMPL

Client side

- AMPL command-line or IDE environment
- Gurobi for AMPL, using front end only

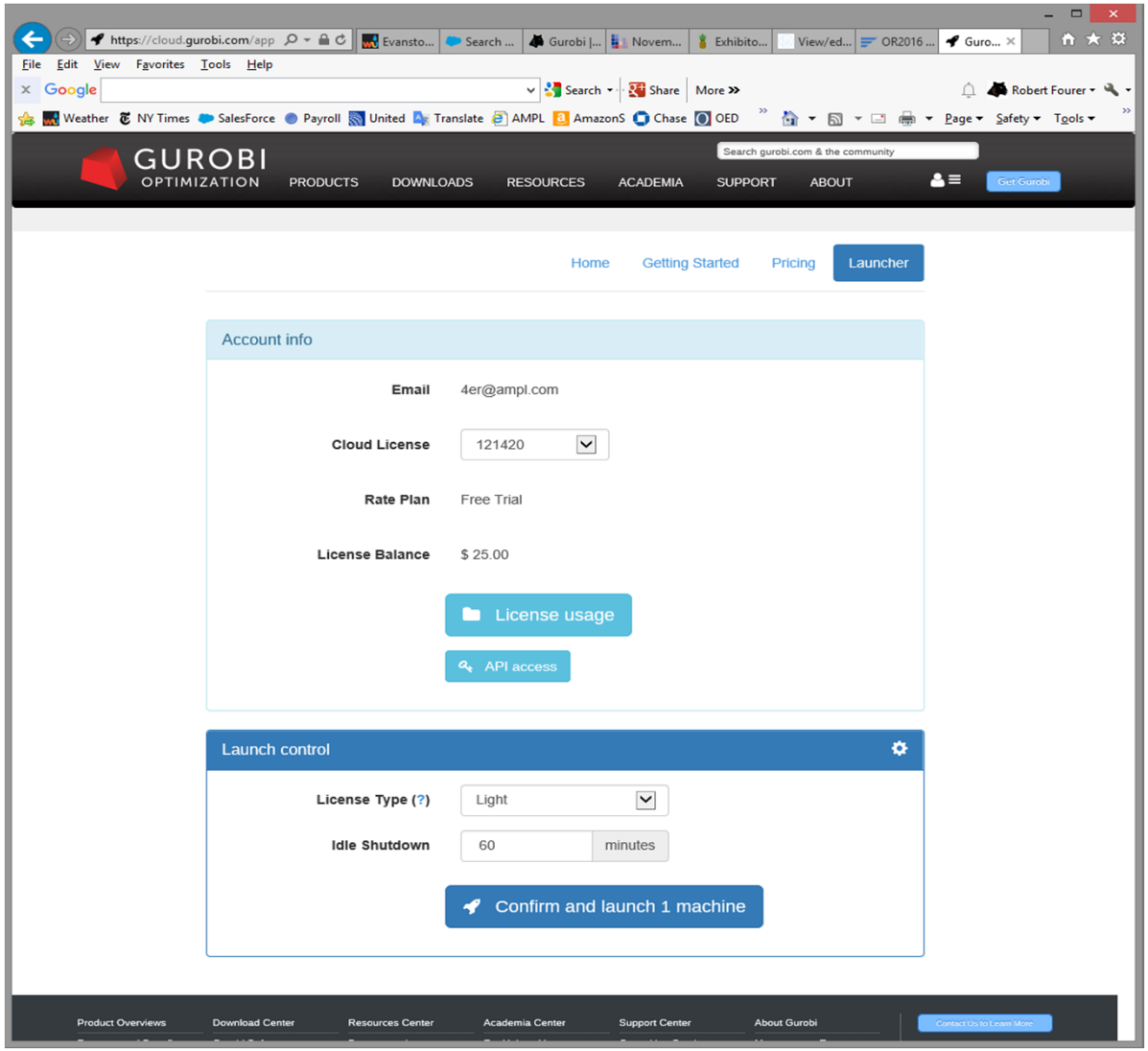
Server side

- Gurobi compute server running MIP solver
- One Amazon Web Services host

. . . aka Gurobi Instant Cloud

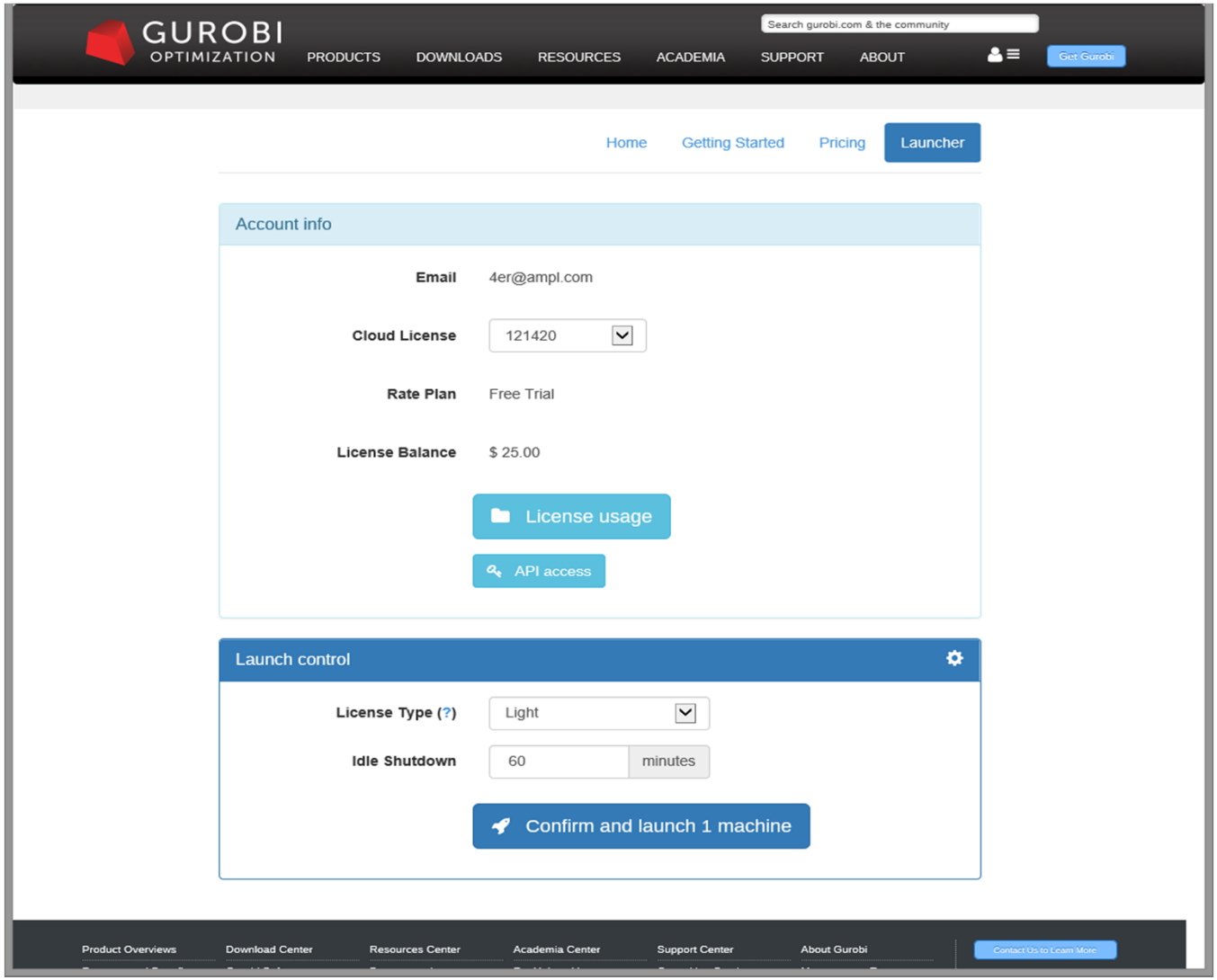
Gurobi Cloud for AMPL

cloud.gurobi.com/app



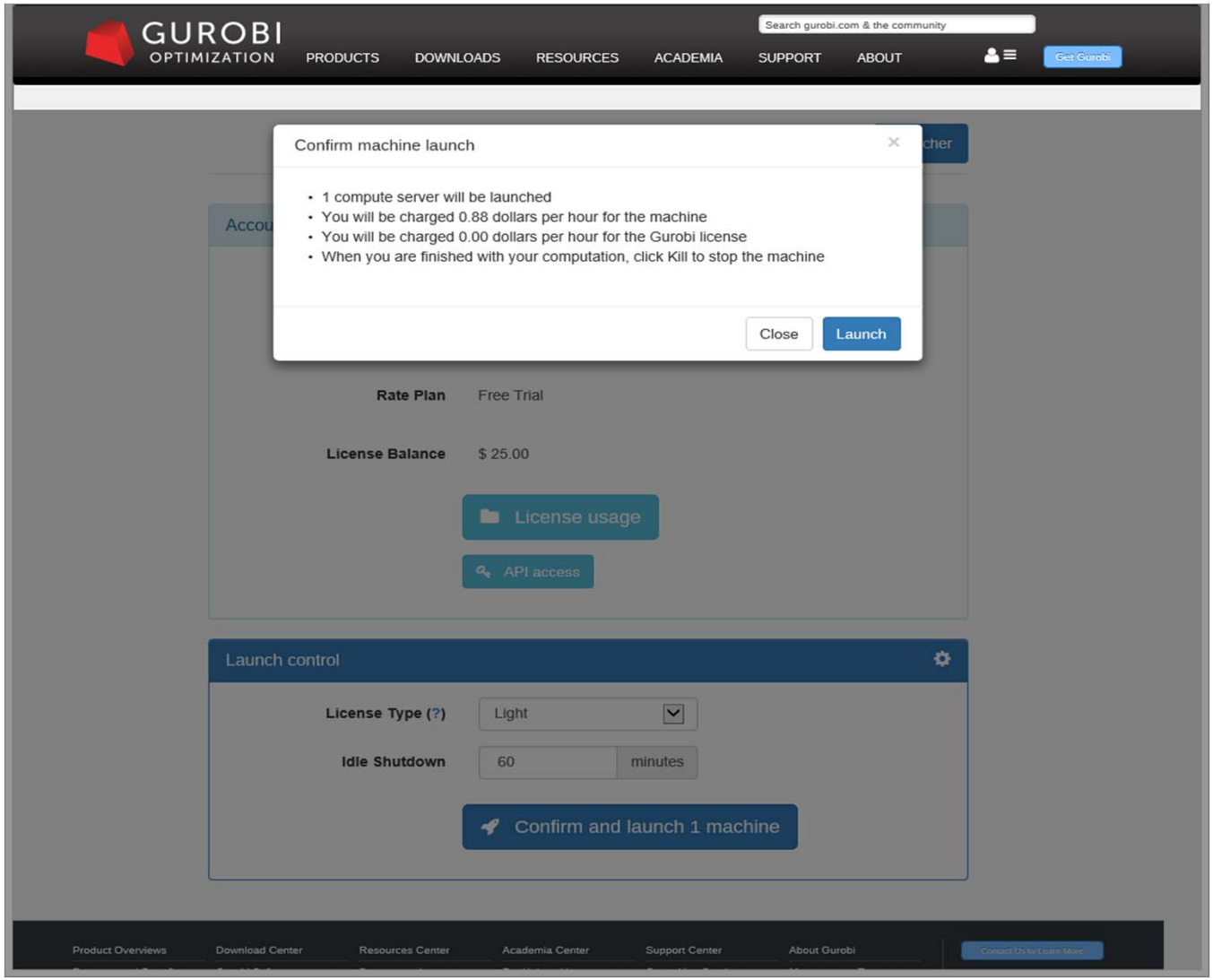
Gurobi Cloud for AMPL

cloud.gurobi.com/app



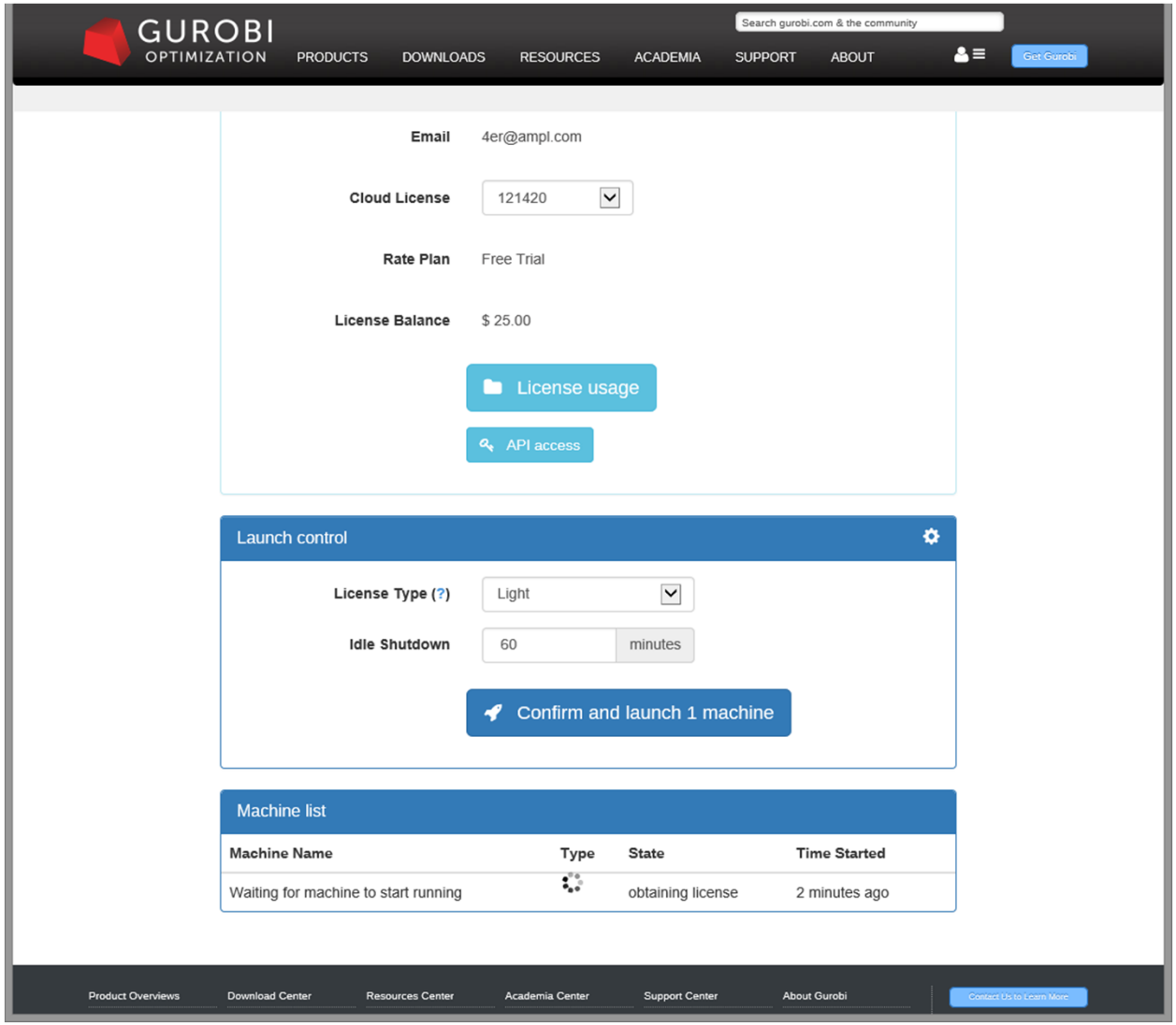
Gurobi Cloud for AMPL

Confirm and Launch



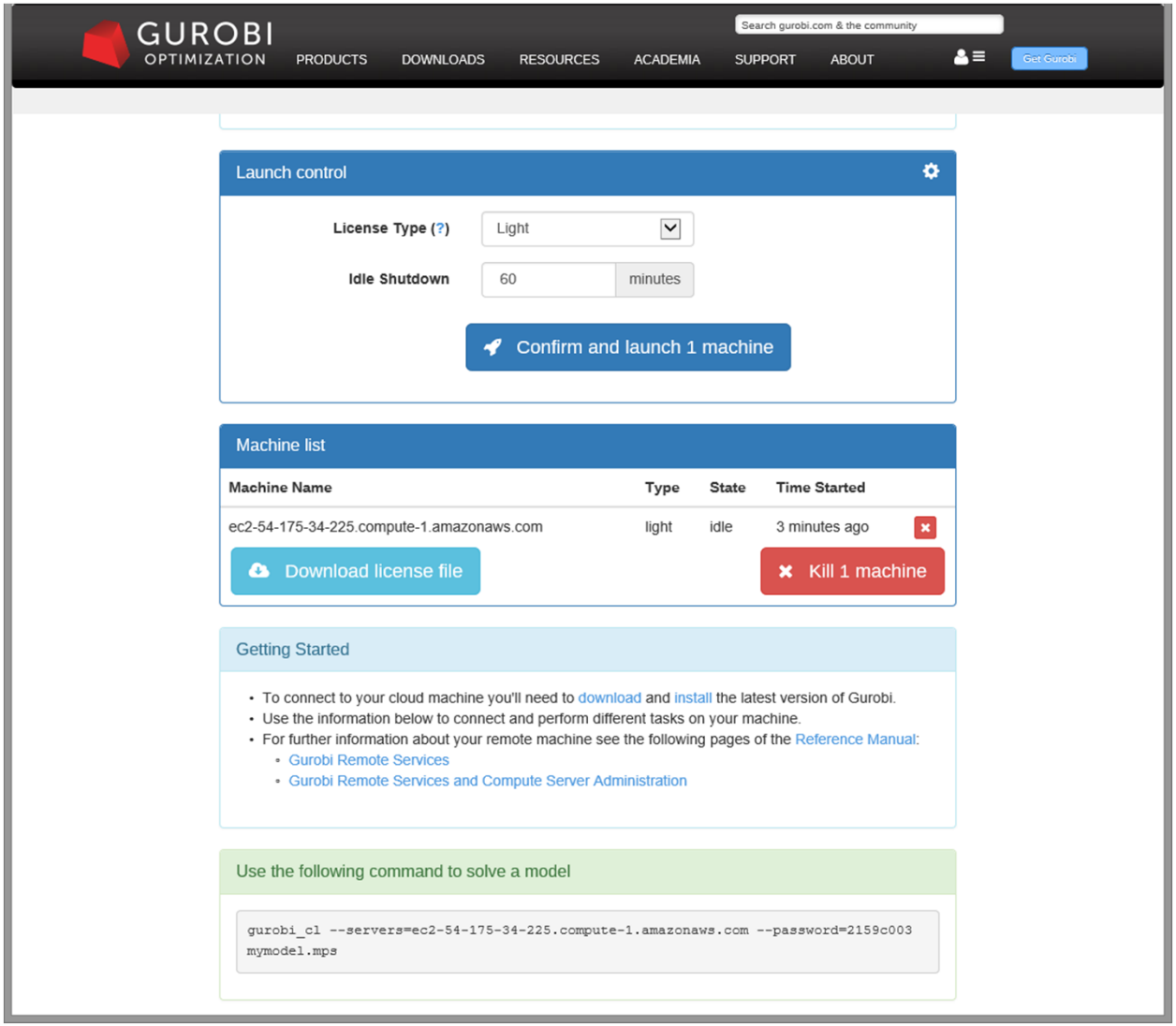
Gurobi Cloud for AMPL

Wait for Machine to Start Running



Gurobi Cloud for AMPL

Get Machine Name and Password



Gurobi Cloud for AMPL

Get Gurobi License File

```
# This is a license file created by the Gurobi Instant Cloud
# Created on Thu, 28 Apr 2016 00:18:42 GMT
# License Id: 121420
# Place this file in the following locations:
#    * C:\gurobi\ on Windows
#    * /opt/gurobi/ on Linux
#    * /Library/gurobi/ on Mac OS X
# Or set environment variable GRB_LICENSE_FILE to point to this file

COMPUTESERVER=ec2-54-175-34-225.compute-1.amazonaws.com
PASSWORD=2159c003
```

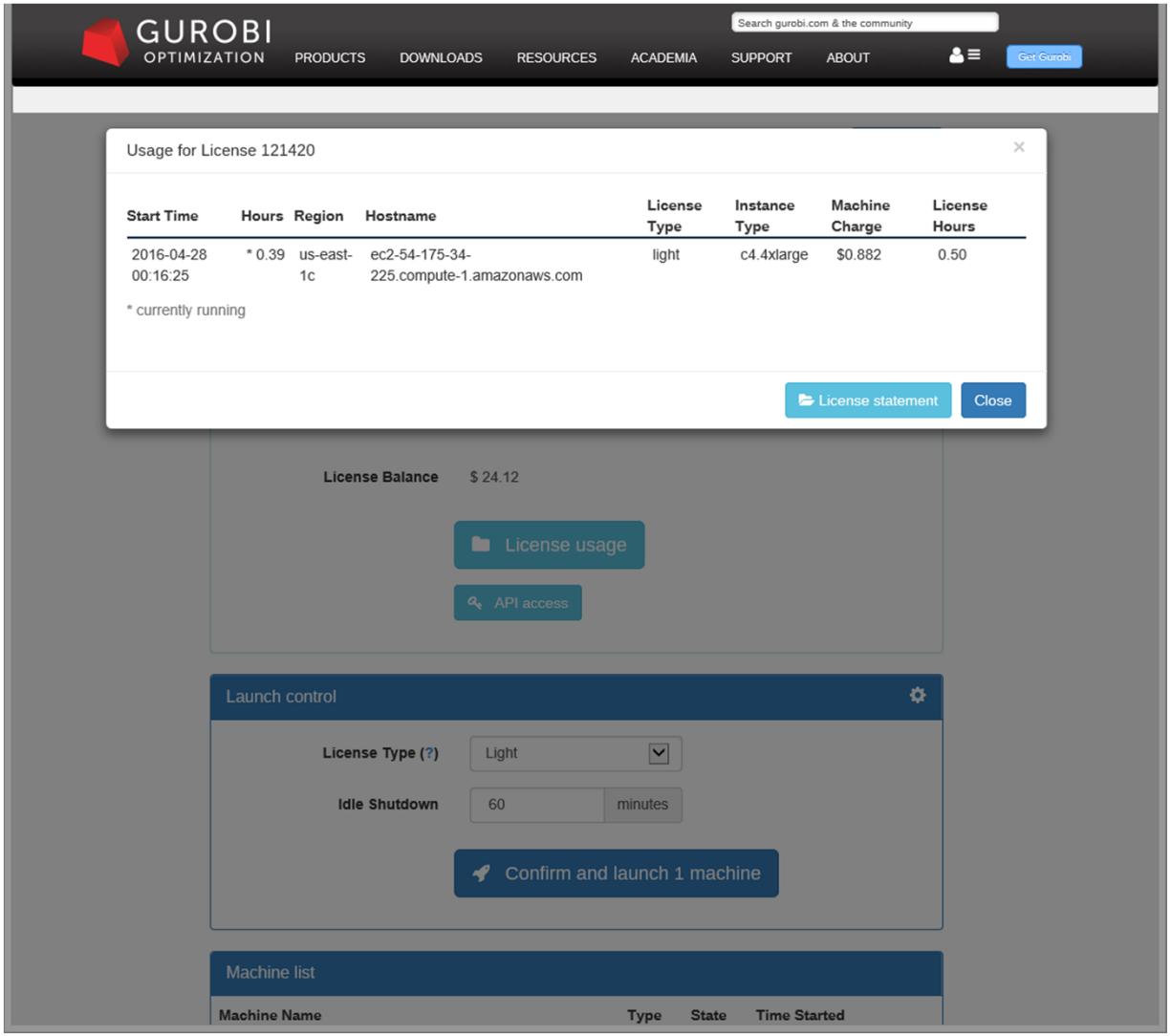
Gurobi Cloud for AMPL

Ready for Use with AMPL

```
ampl: model multmip3.mod;
ampl: data multmip3.dat;

ampl: option solver gurobi;

ampl: option gurobi_options \
       'server=ec2-54-175-34-225.compute-1.amazonaws.com \
        server_password=2159c003';

ampl: solve;

Gurobi 6.5.0: server=ec2-54-175-34-225.compute-1.amazonaws.com
server_password=2159c003

Server capacity available on
ec2-54-175-34-225.compute-1.amazonaws.com - running now

Gurobi 6.5.0: optimal solution; objective 235625
266 simplex iterations
21 branch-and-cut nodes plus
34 simplex iterations for intbasis

ampl: display Trans ...
```

Gurobi Cloud for AMPL

Check Charges



Gurobi Cloud Costs

Gurobi license fees

- $10/hour/socket single-use
- $20/hour/socket unlimited

. . . based on solve times

Amazon machine fees

- $0.11/hour for minimal machine
- $1.76/hour for highest-speed machine
- $2.80/hour for highest-memory machine

. . . based on time machine is active

Discounts and special rules . . .

Gurobi Cloud for AMPL: Assessment

Strengths

- Security
- Reliability (via Amazon)
- Support for multi-server pools
- Support for local modeling clients

Drawbacks (compared to NEOS)

- Licensing issues
  - Need to run Gurobi locally *and* in the cloud
- Separate server management (via Amazon)
  - Complicated to set up
  - Complicated pricing
- Specific to one solver

. . . short of "optimization as an internet resource"