DAVIS PIER

CLOUD COMPUTING: DROPPING THE COST OF OPTIMIZATION

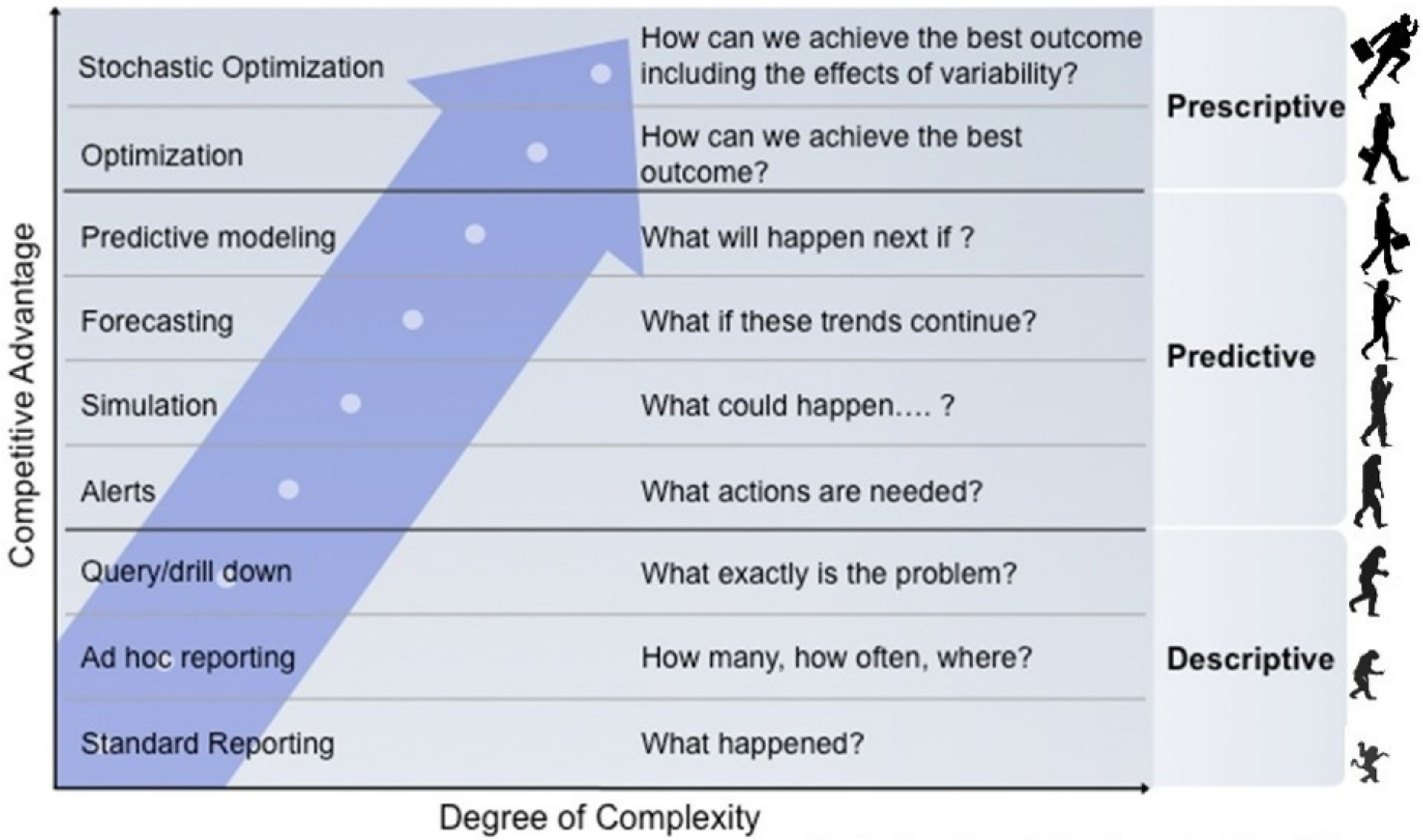
ANDRES COLLART

JUNE 23RD, 2016

AGENDA

1. **Mathematical Optimization**
    1. Two Case Studies
    2. Applications
    3. Requirements
2. **Traditional Approach**
3. **Cloud Approach**
4. **Cost Comparison**

WHAT IS MATHEMATICAL OPTIMIZATION?



Based on: Competing on Analytics, Davenport and Harris, 2007
https://www.optimizedfinancialsystems.com/solutions/what-it-is/

CASE STUDY: UPS ORION

2016 Edelman Award Finalist

UPS - PROBLEM

- 55,000 routes in North America
- 120 stops per route

- 6,689,502,913,449,135,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 choices

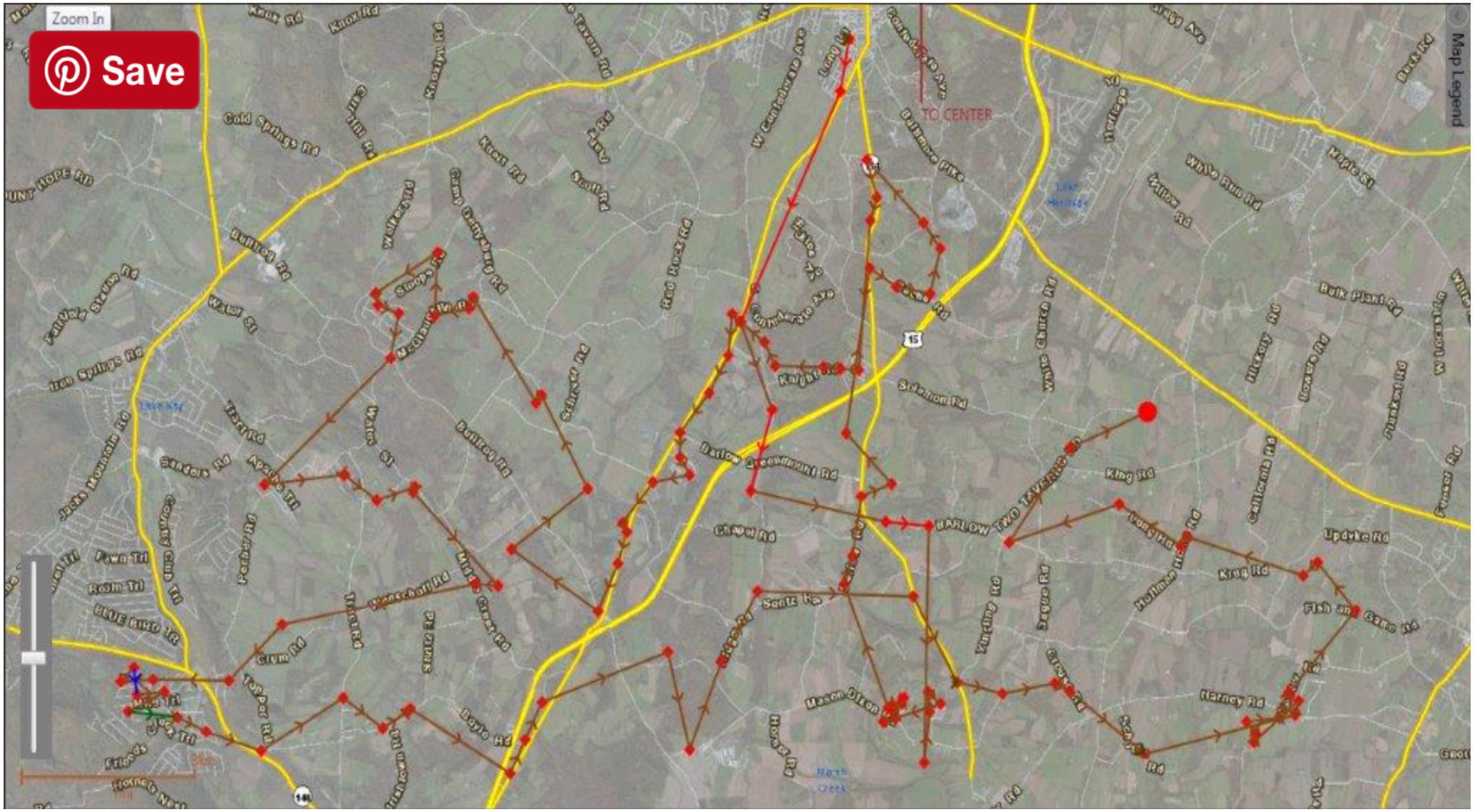
UPS ORION

The On-Road Integrated Optimization and Navigation (ORION) was built and deployed over 9 year by 500-700 full-time staff.

- More than just a TSP solver.
  - Considers customer/driver routine preferences
- Estimated cost of $250M

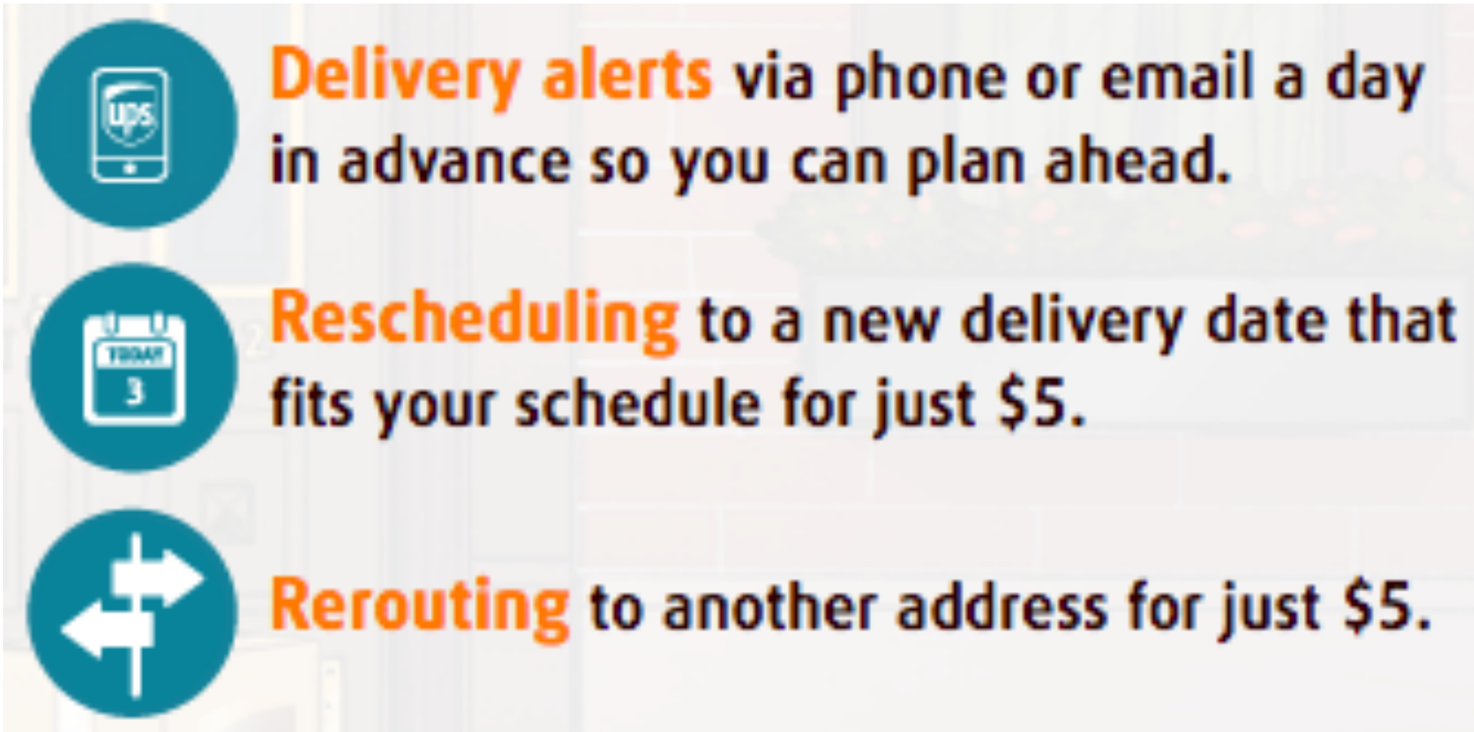
“While most of America is sleeping, ORION is solving tens of thousands of route optimizations per minute.” - UPS

UPS ORION



Zoom In
Save
Map Legend
TO CENTER
Knox Rd
Cold Springs Rd
Bullfrog Rd
Water St
Iron Springs Rd
Fairfield Station Rd
Jacks Mountain Rd
Sanders Rd
Apache Trl
Fawn Trl
Robin Trl
BLUE BIRD TR
Plum Rd
Topper Rd
Boyle Rd
Chapel Rd
Barlow Greenmount Rd
BARLOW TWO TAVERNS RD
Knight Rd
Solomon Rd
Confederate Ave
W Confederate Ave
Baltimore Pike
King Rd
Updyke Rd
Bulk Plant Rd
White Run Rd
Maple St
Mason Dixon Rd
Harney Rd
Fish and Game Rd
Hoffman Rd
California Rd
Hickory Rd
Rock Creek

UPS ORION – MY CHOICE



Source: UPS Website

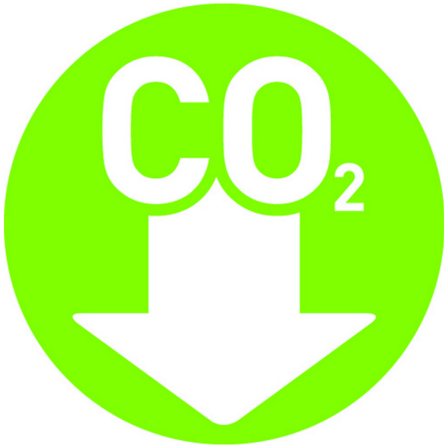
UPS ORION - DEPLOYMENT

To deploy to all 55,000 routes UPS uses 700 trainers that work with each driver for six days.

Mapping → Trainer Rental Ride → Trainer ride with driver → Revise and tune route → Final Ride-Along

UPS ORION - RESULTS

$300,000,000
to
$400,000,000



100,000 metric
tons

10,000,000
gallons

Annually

CASE STUDY: FORD CRASH TESTING

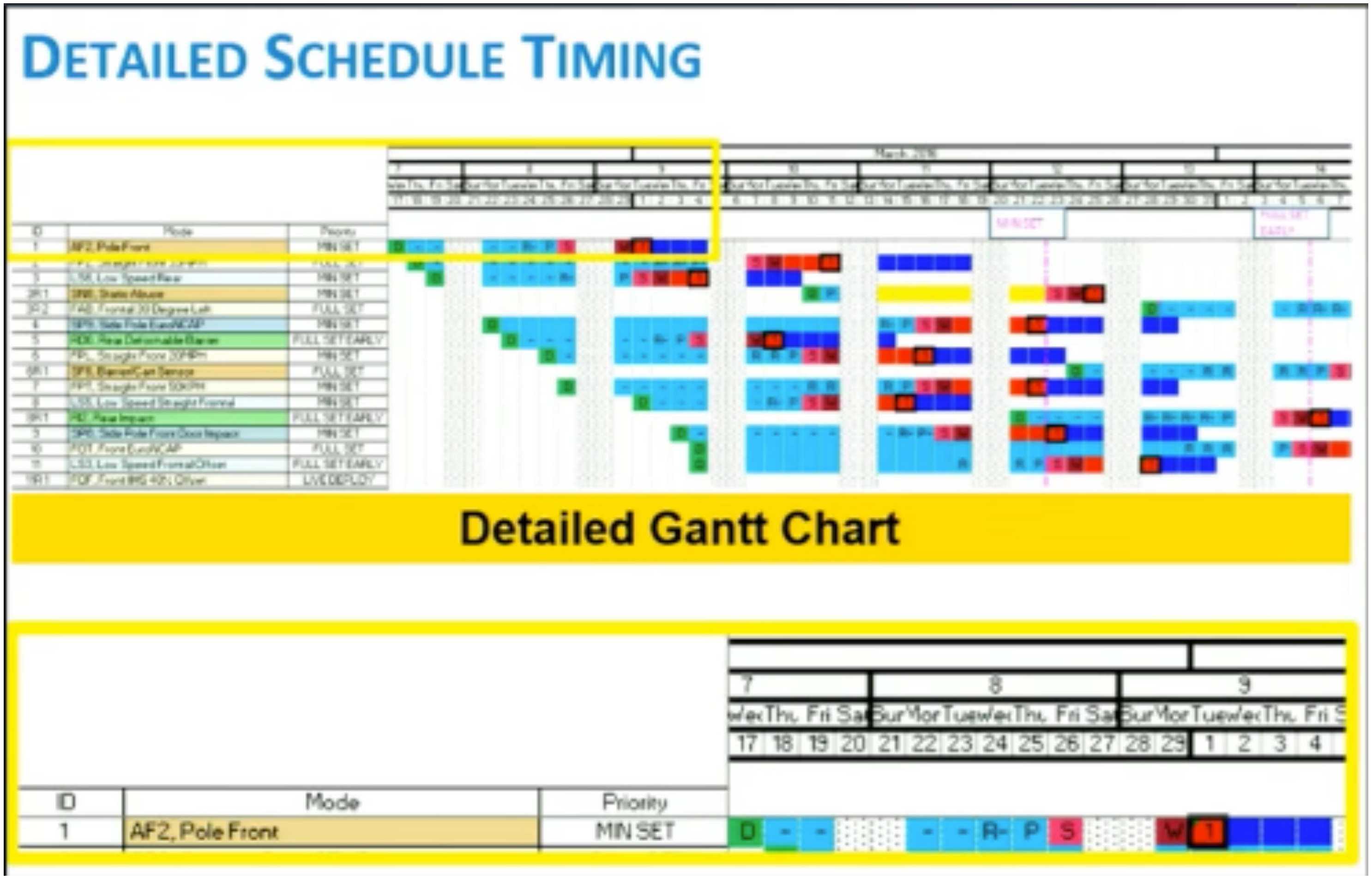
INFORMS Wagner Prize Finalist

By Ford and University of Michigan

FORD CRASH TESTING - PROBLEM

Test vehicle ~ $250,000 each

FORD CRASH TESTING - PROBLEM



Vehicle crash tests have complex schedules!

FORD CRASH TESTING - OPTIMIZATION

- Determine
  - Assignment of tests to prototype vehicles
  - Starting time of each test
- Subject to
  - Conflict and precedence restrictions
  - Test release dates, durations, due dates
  - Vehicle delivery timing
- Optimizing
  - Vehicle utilization
  - Adherence to timing targets
- Computation
  - Ford's High Performance Computing Cluster

FORD CRASH TESTING - RESULTS

- Save vehicles
  - ~$250,000 each
- Faster development cycle
- Free up engineer planning time
  - What-If scenarios
- Schedule quality
- Improved record-keeping
  - Centralized
  - Formalized
  - Standardized

APPLICATIONS OF OPTIMIZATION

APPLICATIONS OF OPTIMIZATION

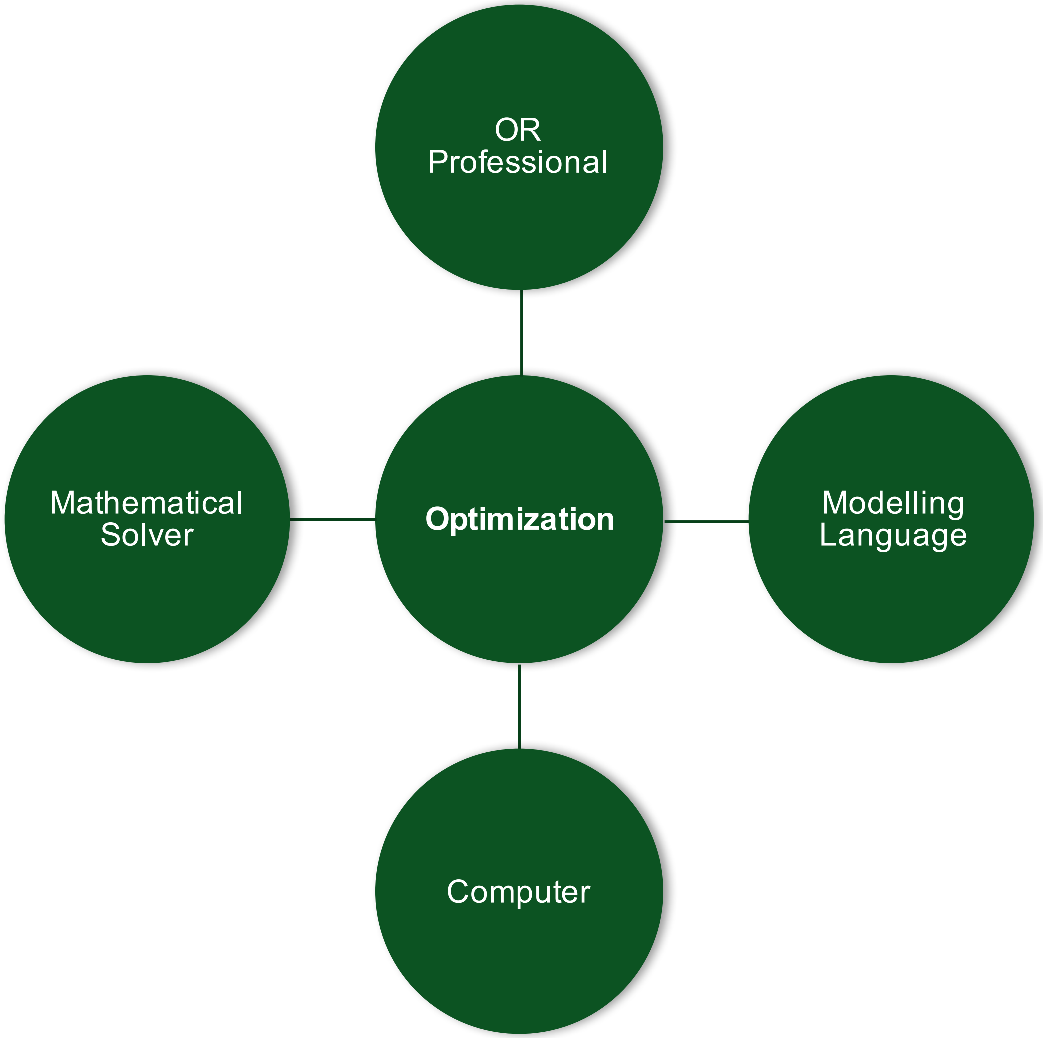
- Production
  - Inventory Optimization
  - Production Mix
  - Machine Allocation
- Distribution
  - Vehicle Routing
  - Driver Scheduling
  - Less-than-Truckload Planning
- Service
  - Workforce Scheduling
  - Advertising and Marketing Mix

APPLICATIONS OF OPTIMIZATION

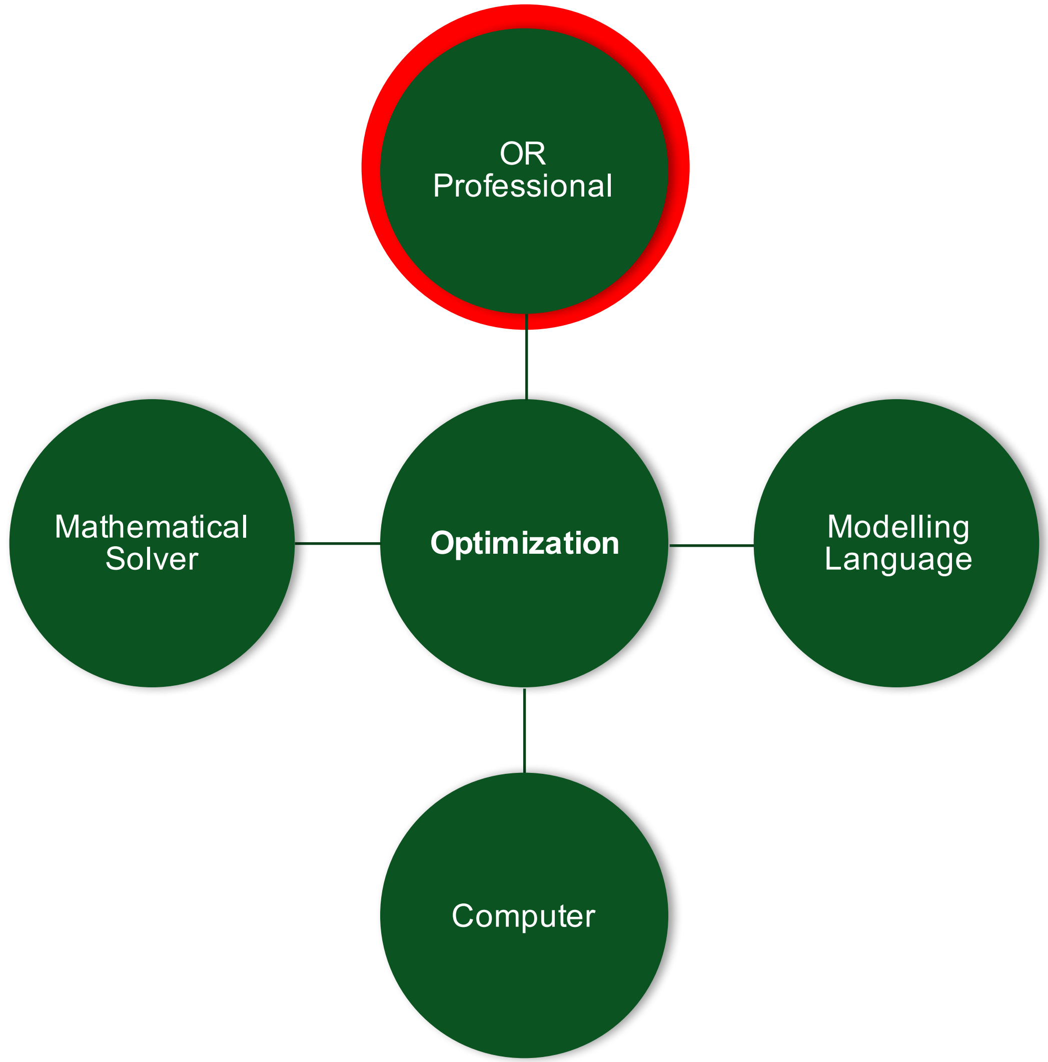
- Energy
  - Unit Commitment
  - Network Flow
  - Hydropower System Flow
- Government
  - Combinatorial Auction
  - Traffic Flow
  - Queuing Management
- Telecom
  - Network Design
  - Field Service Scheduling

HOW DO WE DO IT?

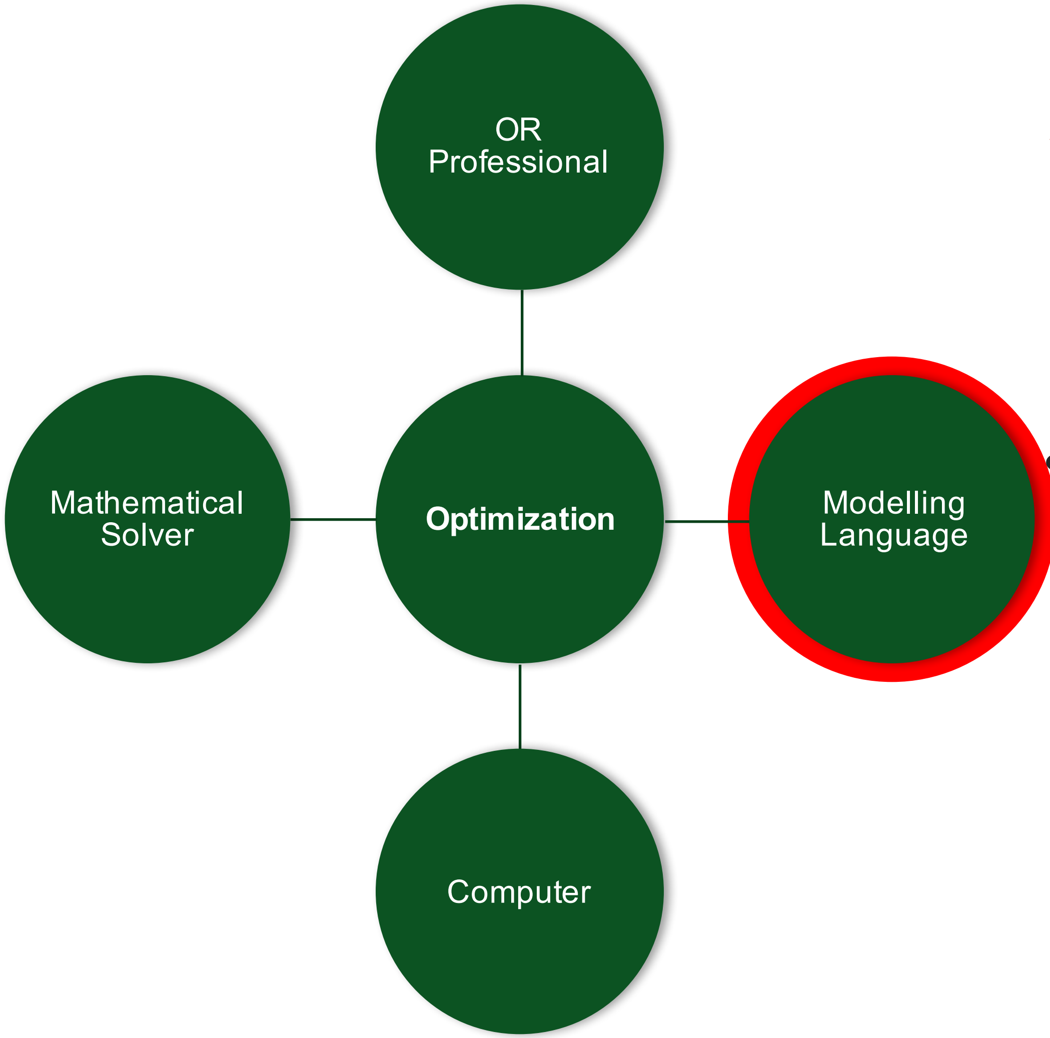
RESOURCES REQUIRED FOR OPTIMIZATION



RESOURCES REQUIRED FOR OPTIMIZATION



RESOURCES REQUIRED FOR OPTIMIZATION



PYOMO

julia

MATLAB

PuLP

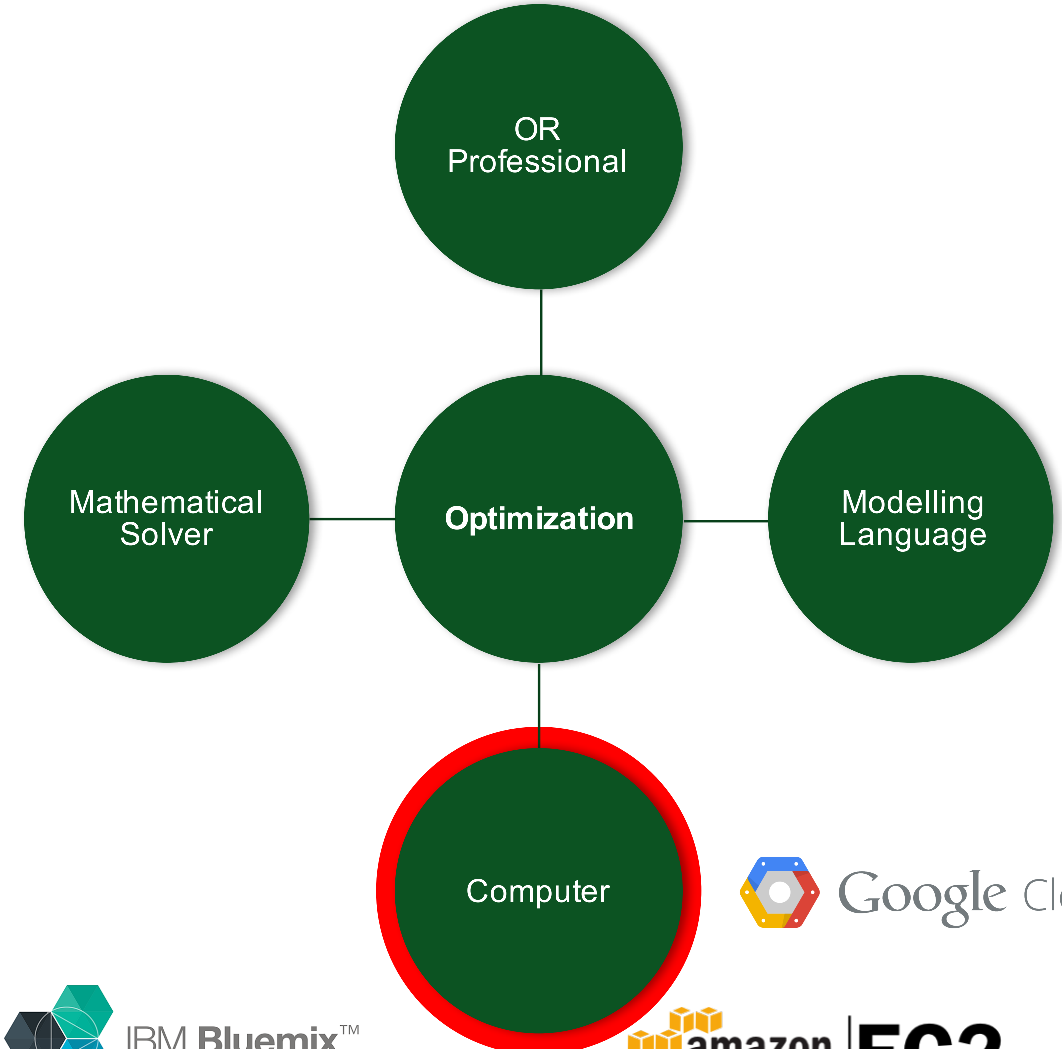
AMPL

GNU MathProg

Google OR-Tools

Fortran

RESOURCES REQUIRED FOR OPTIMIZATION



RESOURCES REQUIRED FOR OPTIMIZATION

GUROBI OPTIMIZATION

IBM ILOG

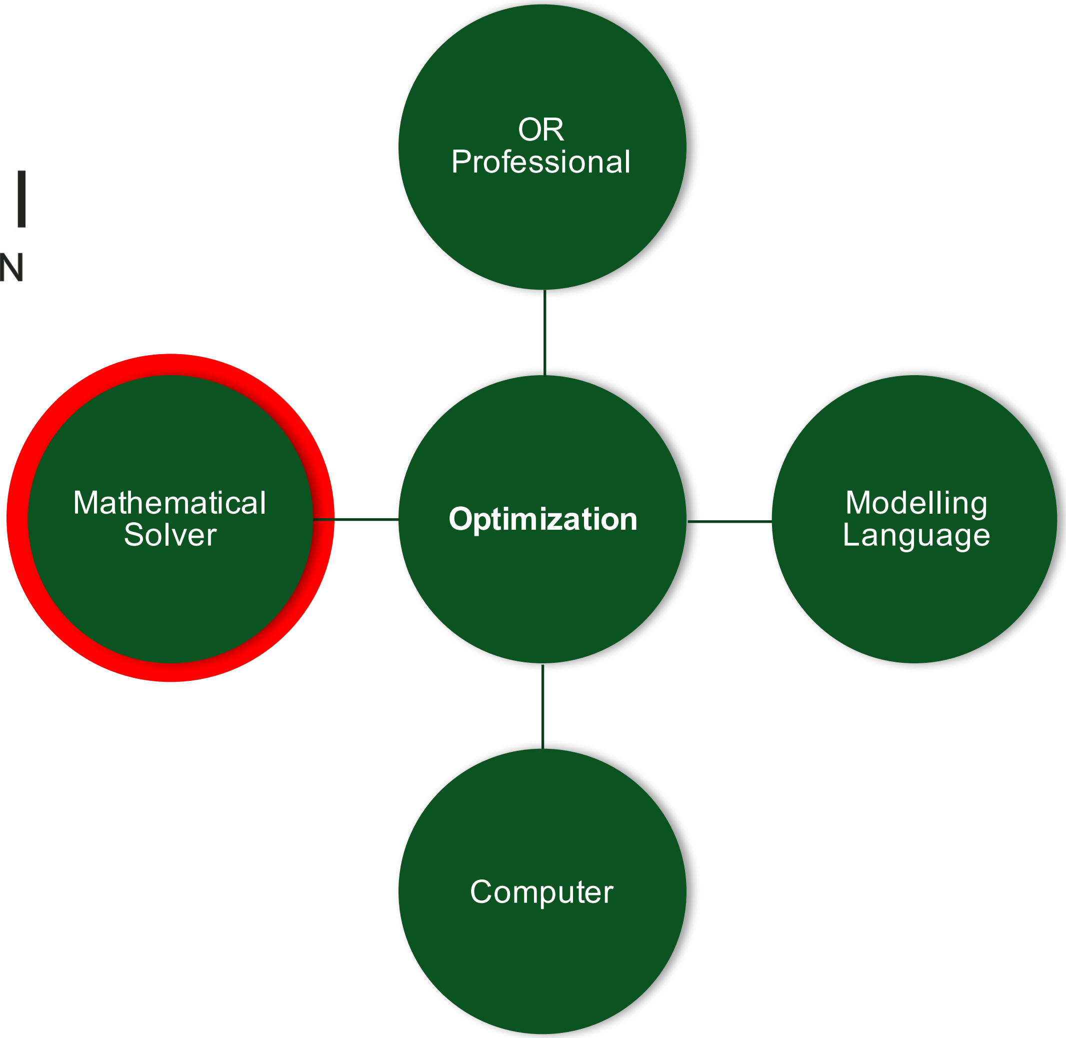
Changing the rules of business

FICO® Xpress

COIN|OR

GLPK

SCIP



TRADITIONAL APPROACH

TRADITIONAL APPROACH

Purchase License → Build Model → Run Model

- Gurobi License cost: $12,000 USD
- ILOG CPLEX License cost: $14,800 USD

Single user license
Support/Updates not included or limited inclusion
Not including hardware

TRADITIONAL APPROACH

- Strengths
  - Keep data in-house
    - ITAR
    - IT Security
  - “Lazy” constraints
  - No internet required (after setup)
- Limitations
  - High commitment required
  - Discrete machines and licenses
  - Low flexibility

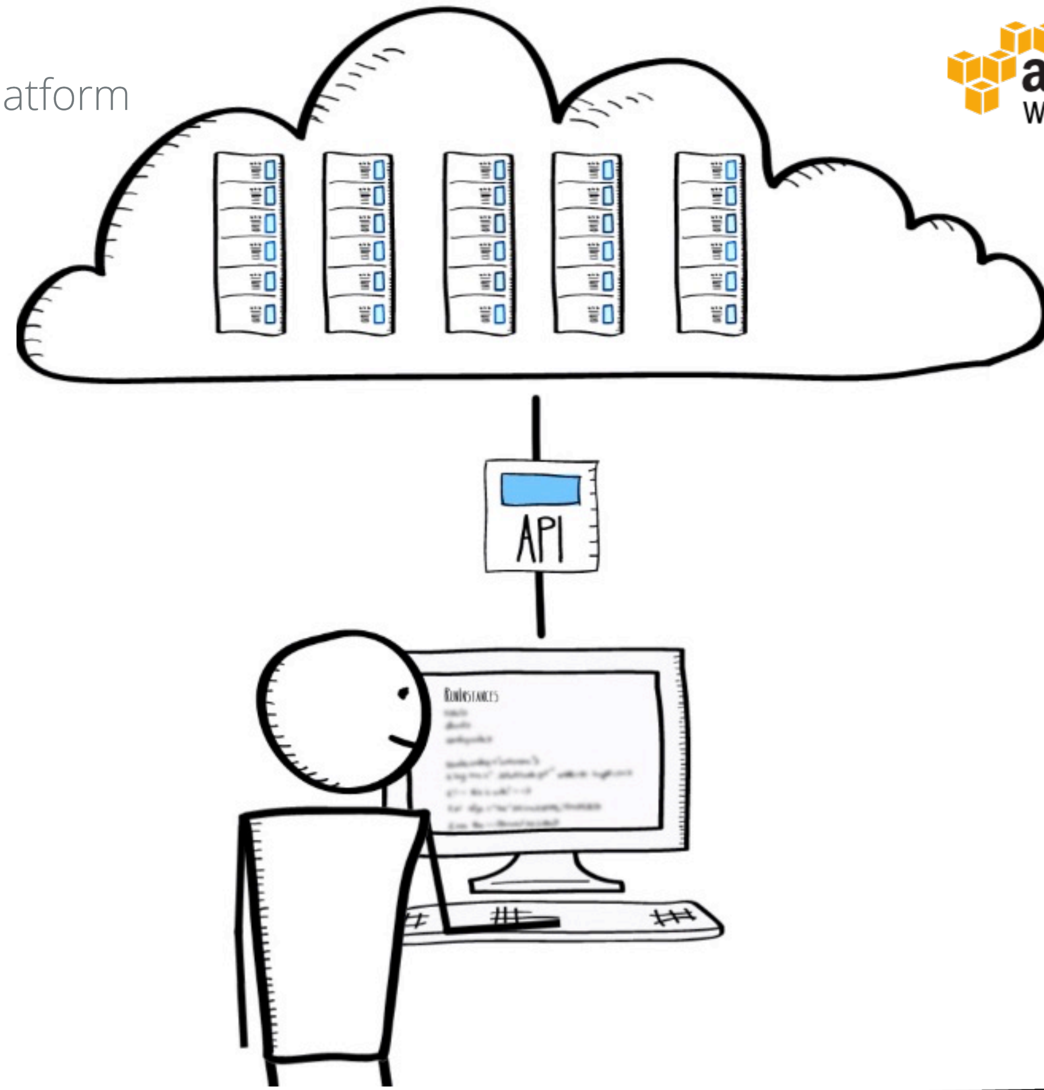
CLOUD APPROACH

CLOUD SERVICES- WHAT ARE THEY?

Google Cloud Platform

IBM Bluemix™

amazon web services™ EC2



CLOUD APPROACH

- Software As a Service (SAS)
  - Gurobi Cloud
  - IBM Decision Optimization on Cloud

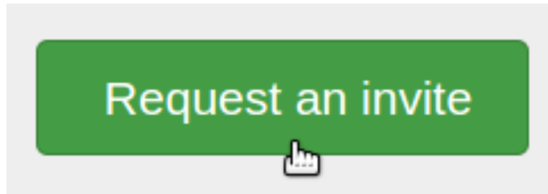
Licensing	
	Light Version $10/Hr
	Full Version $20/Hr

Approach	
	Manual
	Automatic – via API

GUROBI
OPTIMIZATION

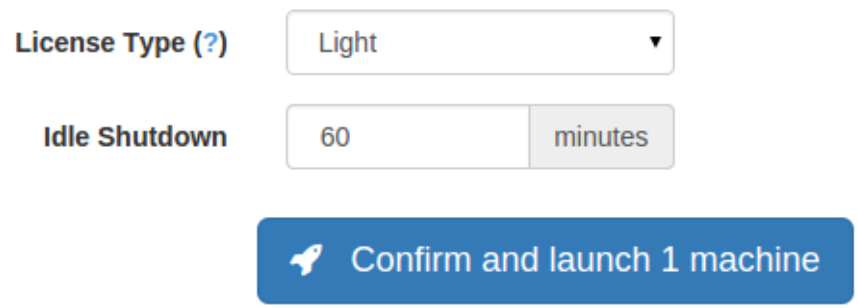
GUROBI CLOUD- MANUAL APPROACH

1. Get access



2. Install Gurobi
   (no license file)

3. Launch machines



4. Manage machines

GUROBI CLOUD- AUTOMATED APPROACH

```python
import time
from instantcloud import InstantCloudClient
from gurobipy import *

def is_machine_ready(machines):
    ready = False
    for machine in machines:
        if machine['state'] == 'idle' or \
           machine['state'] == 'running':
            ready = True
            break
    return ready


ic = InstantCloudClient(YOUR_ACCESS_ID, YOUR_SECRET_KEY)
machines = ic.getmachines()
if len(machines) < 1:
    machines = ic.launchmachines(numMachines=1, machineType="c4.large")

while not is_machine_ready(machines):
    print 'Machine not ready. Sleeping for 30 seconds'
    time.sleep(30)
    machines = ic.getmachines()

machinename = None
userpassword = None
for machine in machines:
    if machine['state'] == 'idle' or \
       machine['state'] == 'running':
        machinename = machine['DNSName']
        userpassword = machine['userPassword']
        break

env = Env("gurobi.log", computeServers=machinename, \
    port=GRB.DEFAULT_CS_PORT, password=userpassword)
```

CLOUD ADVANTAGES

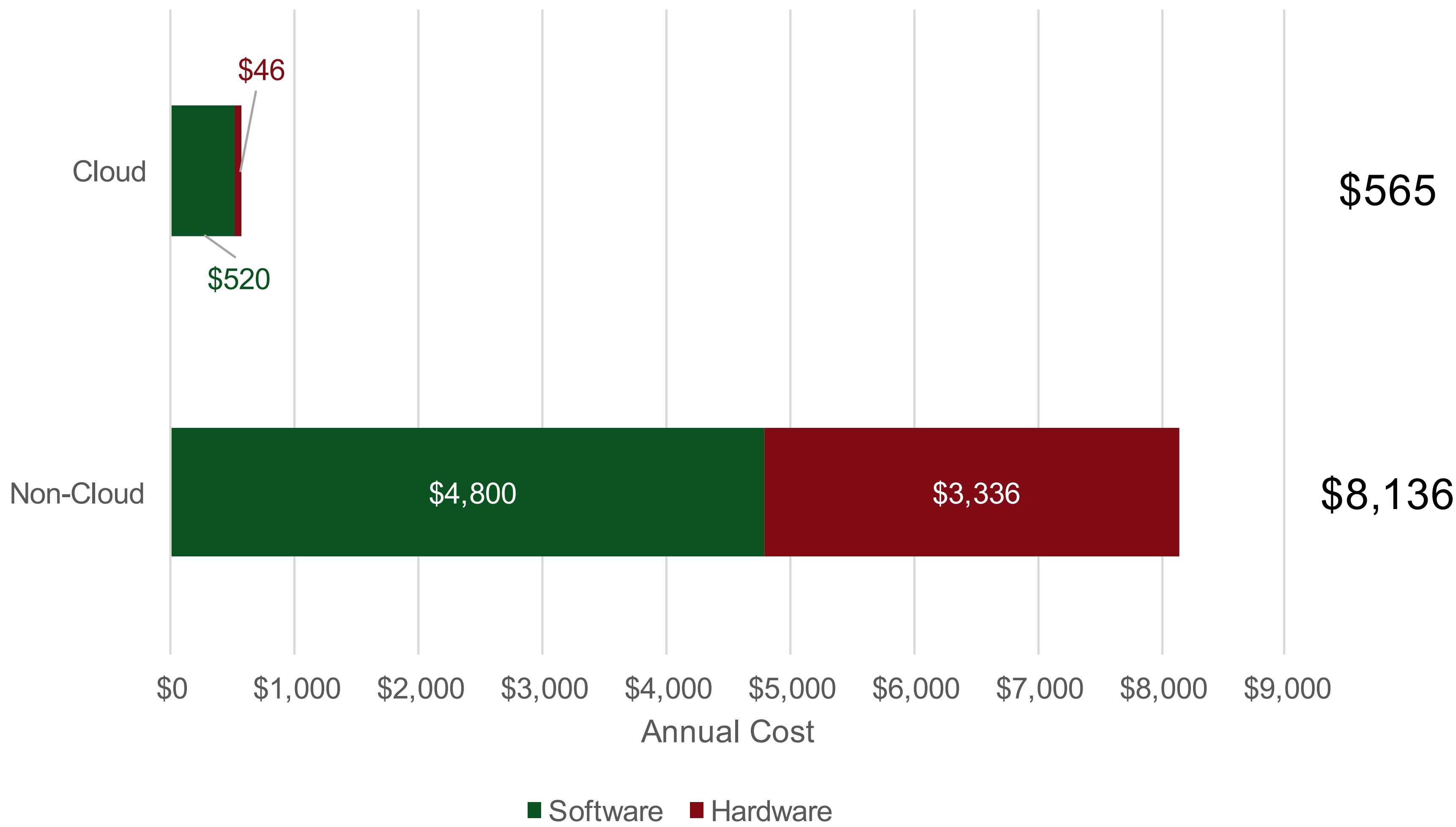
- No Commitment
- Fast Deployment
  - In less than 20 minutes can be fully licensed
- Technical Support included
- Bursts
  - Want 10 computers for an hour? That's about $100.
  - Need to solve one large problem once?
- Testing
  - Can test performance under different computer configurations
- Multi-User

CLOUD LIMITATIONS

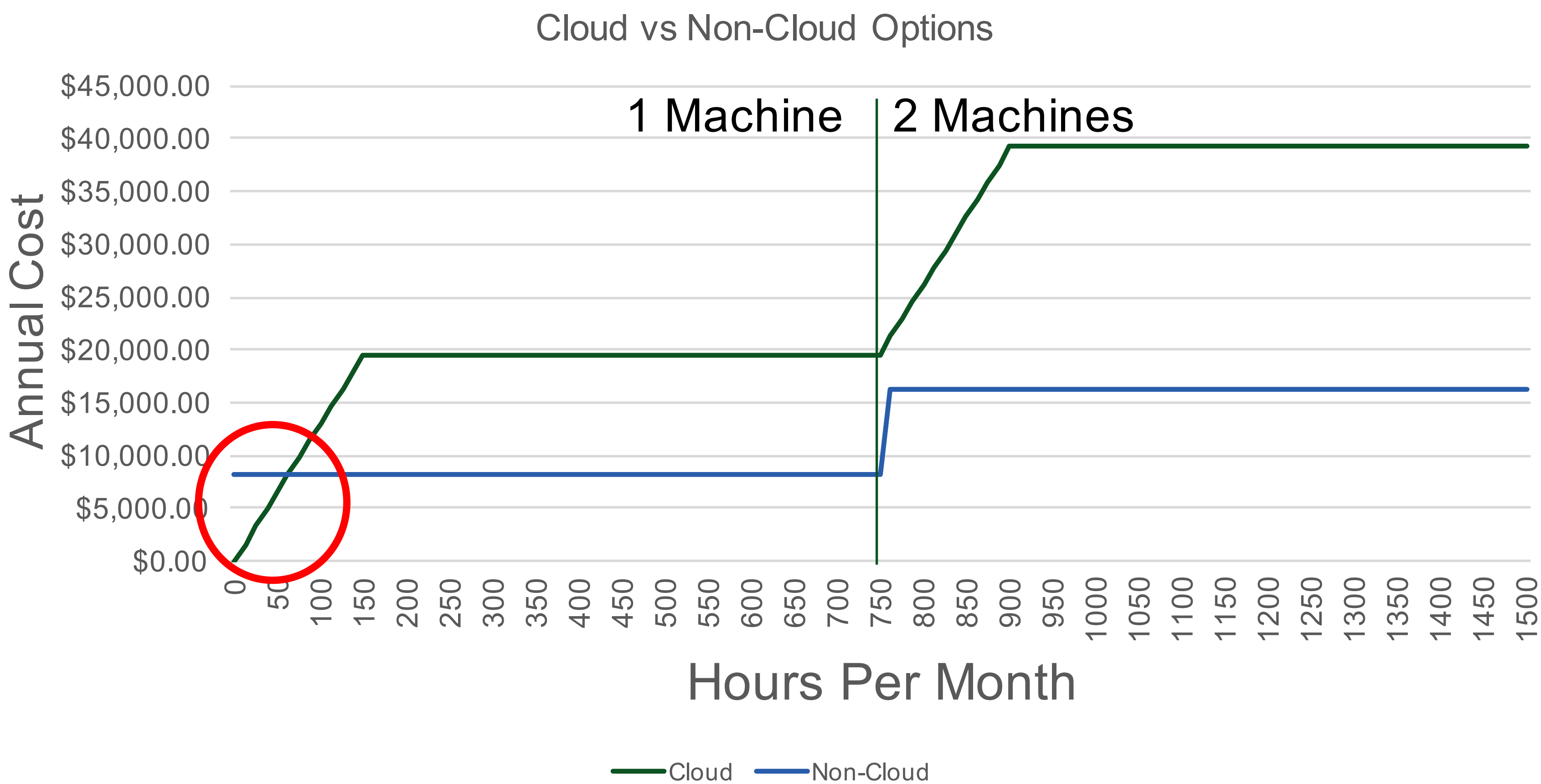
- No “lazy” constraints
  - Lazy constraints are not supported by Gurobi Cloud
- Data must leave facility
  - Automatically encoded using 256-bit AES encryption

COMPARISON

CLOUD VS NON-CLOUD COMPARISON



COMPARISON



Break-even at about 62 hours per month

WHAT IS NOW ECONOMICAL?

Optimization	Results	Frequency	Cloud Cost
Production Scheduling	⬆ Machine utilization ⬇ Order tardiness ⬇ Order makespan	Daily or Weekly	$5-10 per use
Vehicle Routing	⬆ Efficiency ⬇ Fleet size/cost ⬇ Fuel consumption	Daily	$5-10 per use
Supply Chain Analysis	⬆ Efficiency ⬇ Inventory	Ad-hoc	$10-100 per use

QUESTIONS?