Cloud Computing: Helping Humanity to reach the next Final Frontier

Dr. José Luis Vázquez-Poletti

About me
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Directly involved in EU funded projects, such as EGEE and 4CaaS, and StreamCloud (MINECO TIN2012-31518) and MEIGA-METNET-PRECURSOR (AYA2009-14212-C05-05/ESP)

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About Frontiers

Battery recycling
Mobile plant that recycles batteries on the way.

Solar engine
Possible replacement for air conditioning units.

Biodiesel from algae
Attracted investments from US.

Hydrogen fuel
Collaboration with Centro Atómico de Bariloche.

Anti-earthquake systems
Structure reinforcement of legacy buildings and bridges.

UNCuyo and about expanding frontiers

... First HPC in the Cloud tutorial ever in Argentina!

Computing as Humanity’s tool

Konrad Zuse (1910-1995)
First working computer ever (Z3)

Yuri Gagarin (1934-1968)
First man in Space (thanks to a computer)

Neil Armstrong (1930-2012)
First man on the Moon (thanks to the Apollo Guidance Computer)

Don Estridge (1937-1985)
First PC (IBM)

European Union (since 1951)
First reference multinational grid computing infrastructure (LCG, EGEE, EGIt)

Expanded to Latin America (EELA)

Various (since ???)

Cloud computing.

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http://dsa-research.org/jlvazquez/
What is Cloud Computing?

Cloud – A cloud is a visible mass of **microscopic droplets of water or frozen crystals** suspended in the atmosphere.

(Continued)

Cloud Computing layers

- **IaaS (Infrastructure as a Service)**
  - Externalization of computing servers, data warehouses, …
  - Example: Amazon EC2

- **PaaS (Platform as a Service)**
  - Provision of application development and implementation platforms
  - Example: Google Apps

- **SaaS (Software as a Service)**
  - Distribution of software and associated services (support)
  - Example: Google Docs

Cloud infrastructure types

- **Private Cloud**
  - Own physical resources
  - Limited
  - Can be distributed (virtual infrastructure manager is needed)
  - Maximum management power
  - Maintenance costs

- **Public Cloud**
  - 3rd Party resources
  - “Unlimited”
  - Location transparent to the user
  - Only VMs are administered
  - Pay-as-you-go basis

- **Hybrid Cloud**
  - Combination of previous types
  - Virtual infrastructure manager is needed
  - Example: Extra computing power when local resources are overrun

About Mars

Some Martian facts

- 4th planet from the Sun in Solar System
- Iron oxide prevalent on surface gives red color
- Rotational period: 24h40’ hours
- Half the radius of Earth
  - 38% Earth’s gravity
- Thin atmosphere
  - 95% carbon dioxide, 3% nitrogen, 1.5% argon, traces of oxygen and water
  - Methane detected (volcanic, cometary impacts and/or microbial?)
  - No magnetosphere
- Once had large-scale water coverage
  - Now only in poles and mid-latitudes

Why go to Mars?

- Getting out of Earth to discover our origins
- Comparative planetology can combine the insights gained from Mars and Earth (i.e. Martian climate development).
- Exploring the nature of (possible) extraterrestrial life to understand ours.
- Revaluing the Scientific profession
  - The unknown territory and the limited predictability of events together with the long delay of signals (10’ to 45’) require an unique flexibility and talent to improvise.
  - NASA places its bets on astronauts and scientists for accomplishing the complex exploration of Mars.
Why go to Mars?

"Peace and Prosperity"

Mars missions include technological, economical, political, and cultural aspects which would push the limits of technological innovations, promote a peaceful cooperation and a sense of global unity.

Mars in times of crisis

Mars missions create interesting jobs (more than 500,000 people were involved in the Apollo program) and provide motivation for scientific education.

Cost-efficient exploration missions would require a well-balanced combination of manned and unmanned activities complementing each other. Achievements can be applied to other fields (i.e. GPS, velcro, teflon, smoke detectors, diapers, ...).

Missions to Mars

<table>
<thead>
<tr>
<th>Mission</th>
<th>Country</th>
<th>Launch</th>
<th>Results</th>
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<tbody>
<tr>
<td>Mariner 7</td>
<td>USSR</td>
<td>07/25/1973</td>
<td>Operative in Mars orbit, Phobos photos</td>
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<tr>
<td>Mars 5</td>
<td>USSR</td>
<td>07/21/1973</td>
<td>Mars 5,500 km during several years</td>
</tr>
<tr>
<td>Mars 4</td>
<td>USSR</td>
<td>07/25/1973</td>
<td>Mars 5,500 km during several years</td>
</tr>
<tr>
<td>Mariner 8</td>
<td>USA</td>
<td>08/05/1973</td>
<td>Mars 6,500 km during several years</td>
</tr>
<tr>
<td>Viking 1</td>
<td>USA</td>
<td>08/09/1973</td>
<td>Surface module sent signals for 20 seconds</td>
</tr>
<tr>
<td>Viking 2</td>
<td>USA</td>
<td>08/20/1975</td>
<td>Surface module lost (Beagle 2 destroyed)</td>
</tr>
<tr>
<td>Zond 1</td>
<td>USSR</td>
<td>10/24/1962</td>
<td>First artificial satellite of Mars</td>
</tr>
<tr>
<td>Zond 2</td>
<td>USSR</td>
<td>10/14/1960</td>
<td>Second successful module</td>
</tr>
<tr>
<td>Zond 3</td>
<td>USSR</td>
<td>10/10/1960</td>
<td>Third artificial satellite of Mars</td>
</tr>
<tr>
<td>Mariner 3</td>
<td>USA</td>
<td>03/27/1969</td>
<td>First Mars photos (21)</td>
</tr>
<tr>
<td>Mariner 4</td>
<td>USA</td>
<td>02/24/1969</td>
<td>Mars 3,516 km. Photograhies. Passed by Mars 9846 Km.</td>
</tr>
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<td>Mariner 5</td>
<td>USA</td>
<td>07/18/1965</td>
<td>Operative for 7 years</td>
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<td>Mars 1</td>
<td>USSR</td>
<td>11/01/1962</td>
<td>Exploded in terrestrial orbit</td>
</tr>
<tr>
<td>Mars 2</td>
<td>USSR</td>
<td>11/04/1962</td>
<td>Exploded in terrestrial orbit</td>
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<tr>
<td>Mars 3</td>
<td>USSR</td>
<td>11/28/1964</td>
<td>Exploded in terrestrial orbit</td>
</tr>
<tr>
<td>Mars 4</td>
<td>USSR</td>
<td>06/04/1964</td>
<td>Exploded before reach terrestrial orbit</td>
</tr>
<tr>
<td>Mars 5</td>
<td>USSR</td>
<td>11/05/1964</td>
<td>Exploded before reach terrestrial orbit</td>
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<tr>
<td>Mariner 8</td>
<td>USA</td>
<td>03/27/1969</td>
<td>Operative during several years</td>
</tr>
<tr>
<td>Mariner 9</td>
<td>USA</td>
<td>05/28/1971</td>
<td>First robotic vehicle. More than 160,000 photos</td>
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<td>Mars 1969 A</td>
<td>USSR</td>
<td>11/17/1964</td>
<td>Surface module sent data approaching Mars</td>
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<tr>
<td>Mars 1969 B</td>
<td>USSR</td>
<td>04/02/1969</td>
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<td>Mariner 10</td>
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<td>Mariner 11</td>
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<td>08/14/2005</td>
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<tr>
<td>Mars 1971 B</td>
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<td>08/20/2005</td>
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<td>Mars 1971 F</td>
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<td>Mars 1971 K</td>
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<td>Mars 1971 L</td>
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<td>Mars 1971 M</td>
<td>USA</td>
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<td>Mars 1971 O</td>
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<td>08/20/2005</td>
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<td>Mars 1971 Q</td>
<td>USA</td>
<td>08/20/2005</td>
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<tr>
<td>Mars 1971 R</td>
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<td>Mars 1971 S</td>
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<td>08/20/2005</td>
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<td>Mars 1971 T</td>
<td>USA</td>
<td>08/20/2005</td>
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<td>Mars 1971 U</td>
<td>USA</td>
<td>08/20/2005</td>
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<tr>
<td>Mars 1971 V</td>
<td>USA</td>
<td>08/20/2005</td>
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<td>Mars 1971 W</td>
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<td>08/20/2005</td>
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<tr>
<td>Mars 1971 X</td>
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<td>Mars 1971 Y</td>
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<td>08/20/2005</td>
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</tr>
<tr>
<td>Mars 1971 Z</td>
<td>USA</td>
<td>08/20/2005</td>
<td>Surface module lost (Beagle 2 destroyed)</td>
</tr>
</tbody>
</table>


Emerged at NASA Ames Research Center and now supported by staff and infrastructure at Ames and at NASA Goddard Space Flight Center

“Computing Container as a Service”

- Open-source cloud computing project and service developed to provide an alternative to the costly construction of additional data centers whenever NASA scientist or engineers require additional data processing.
- Each shipping container data center can hold up to 15,000 CPU cores or 15 petabytes of storage while proving 50% more energy efficient than traditional data centers.

- Virtualization technologies
  - XEN and KVM hypervisors
  - Eucalyptus and then OpenStack virtual infrastructure manager

Ok, but... Where are the Clouds?
NASA

Some recent applications

SERVIR
• Integrates satellite observations, ground-based data and forecast models
• Monitors environmental changes and improves response to natural disasters

SPoRT Center
• Transitions unique NASA satellite observations and modeling capabilities to NOAA’s National Weather Service
• Improves the analysis and prediction of weather events occurring within a 0-48 hour time-frame.

NASA uses Amazon EC2 (December 2010)

ATHLETE (All-Terrain Hex-Limbed Extra-Terrestrial Explorer)
• High resolution satellite images
• Process needed for guidance

Application: Polyphony
• Evaluates cloud capabilities
• Delivered to the Mars Science Laboratory

“AWS’s resources completed the work in less than two hours on a cluster of 30 Cluster Compute Instances. This demonstrates a significant improvement over previous implementations.”

“(Polyphony) allowed us to process nearly 200,000 Cassini images within a few hours under $200 on AWS.”

1 year before, in the Old World...

Mars MetNet

The MetNet mission to Mars is based on a new type of semi-hard landing vehicle called MetNet Lander (MNL).

The scope of the MetNet Mission is eventually to deploy several tens of MNLs on the Martian surface.

The basic ideas of MetNet were cast by the FMI-team already in late 1980’s. The development work started in the year 2000.

The first step in the MetNet Mission is to have a MetNet Mars Precursor Mission (MMPM) with a few MNLs deployed to Mars.

Mars MetNet

Atmospheric Science Mission to Mars initiated and defined by the Finnish Meteorological Institute (FMI).

Put together by FMI, Lavochkin Association (LA), the Russian Space Research Institute (IKI) and Instituto Nacional de Técnica Aeroespacial (INTA).

Universidad Complutense de Madrid (UCM) participates within the MEIGA Project (Science Team).

DSA Research Group from UCM collaborates by bringing Cloud Computing where it would benefit the Mission’s applications and systems.
Mars MetNet

Application #1

Starting issues

- Probe landing location is needed for onboard instrument Calibration.
- Exact landing coordinates are unknown.
- Landing area (wide set of coordinates) is only determined 1h30’ before entry procedure.
- Compass is useless and GPS is not offering service (yet) on Mars.

Approach

- Orientate through well known celestial objects

Phobos: The biggest Martian moon. Discovered in 1877 by Asaph Hall or... by Jonathan Swift in his book "Gulliver’s Travels" (1726).

The nearest moon to its planet in all the Solar System (6000 Km)
Orbit: 3 times/day aprox.
Diameter: 28x20 Km
Gravity: 0.00067g
Escape velocity: 25 Km/h

Very interesting effects on the Martian surface, specially eclipses.

Phobos tracing application developed within the MEIGA project.

Phobos tracing will help in:

1. Obtaining probe landing coordinates
2. Data analysis (Eclipses = low radiation)


Simulation in 1 area = 800 years in 1 coordinate
11 days 8 hours (without parallelism)

Using VMs from Amazon EC2

¿Which Interval/Task? ¿Which type/number of VMs?

A Public Cloud Example: Amazon

<table>
<thead>
<tr>
<th>Machine Type</th>
<th>Cores</th>
<th>C.U.</th>
<th>Memory</th>
<th>Storage</th>
<th>Price in USA</th>
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</thead>
<tbody>
<tr>
<td>Standard On-Demand Instances</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small (Default)</td>
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<td>1</td>
<td>17GB</td>
<td>16GB</td>
<td>$0.10/hour</td>
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<tr>
<td>Large</td>
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<td>2</td>
<td>7.5GB</td>
<td>8GB</td>
<td>$0.40/hour</td>
</tr>
<tr>
<td>Extra Large</td>
<td>4</td>
<td>2</td>
<td>15GB</td>
<td>16.6GB</td>
<td>$0.80/hour</td>
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<tr>
<td>High CPU On-Demand Instances</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>2</td>
<td>2.5</td>
<td>7GB</td>
<td>8GB</td>
<td>$0.35/hour</td>
</tr>
<tr>
<td>Extra Large</td>
<td>8</td>
<td>2.5</td>
<td>16.6GB</td>
<td></td>
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Machine Type | Price in USA |
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</tr>
</tbody>
</table>

Model for best strategies by means of Time and Cost

Mars MetNet: Phobos

More in detail...

Possible solution: 37 HighCPU Medium Machines (1h ~ $7.50)

What is the price of a similar cluster for the chosen solution?

Example:

HP ProLiant DL170g G6 Server - $4,909 x 37 nodes = $181,633

What about administration? Electricity? Physical Security?

How many times will it be used at full power? Amortization?

Viking Landers

Application #2

Starting issues

- 2 landers (1976-1980) with different sensors
- Data taken in different intervals and some got corrupted.
- Measurements will help MetNet.

Approach

- Some of the “inconsistent” data could be provoked by Phobos (or Deimos) eclipses.
- Other may indicate a temporal malfunction of sensors.

Example:

HP ProLiant DL170g G6 Server - $4,909 x 37 nodes = $181,633

What about administration? Electricity? Physical Security?

How many times will it be used at full power? Amortization?

Mars MetNet

Application #3

Starting point

- Mars Science Laboratory (Curiosity)
- Phobos eclipses prediction
- Sol 37 (13/09/2012)
- Sol 41 (17/09/2012)

Results

- On-site validation
  - <1 second precision!!
- The application is ready for its use on the Mars MetNet probes

Mars MetNet

Application #4

Starting point

- Need of a Martian meteorological model

Computational workplan

- Cost optimization of terrestrial meteorological models
  - Will apply to Martian models later
- Validation of proposed Martian models
  - Huge amount of data process

Models:

- GFS: free data, sometimes imprecise. 2 level computation.
- ECMWF: restricted access data. 1 level computation.
Cloud Computing is taking the role of ancient computing systems which brought Humanity to Space. Mars represents the nearest frontier to be broken by Humanity. As in the rest of scenarios, achievements will directly affect technology and general knowledge. Cloud Computing won’t be an exception.