A NASA Perspective on Open Source Software

American Institute of Engineers
Military Open Source Software Conference
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Inherited from the presentation by djbyrne at jpl.nasa.gov
at USENIX LISA 2006 December 6, 2006
Common Goals

• FOSS (Free/Open Source Software) developers and NASA folks have a lot in common
  – Dedicated to expanding the pool of information floating freely through society
    • Space Act NASA Charter: “... provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof...”
    • http://www.nasa.gov/offices/ogc/about/space_act1.html
  – Focused on the cutting edge, creating tools and capabilities which did not previously exist
  – I like to think that FOSS community donations of code are reciprocated with knowledge about weather systems, climate, and basic science
About the speaker

• Software geek
  – Whatever language
  – Whatever platform (well, I’m “done” with one...)
• SysAdmin
• System Engineer
• Programmer again!
  – As long as the SysEng stuff is done first
Open Source in Space

- Explores our Solar System
- Observes the Universe
- Is used to develop new algorithms and code
- Is used to move and analyze data by flight operations on the ground
The Open Advantage

• Faster
  – Procurement cycles alone... Oy!
  – Bug fix turn-around times, or we can do ‘em ourselves and give ‘em back
  – Feature additions - ditto, but we can only give back after a lot of paperwork (or contract for them)

• Reliability
  – We tend to find bugs which don’t bother other customers. We live at or beyond the border cases
  – Full system visibility is key to characterization and resolution
Open Advantage, cont

• **Interoperability and Portability**
  – Our industry, academic, and international partners can use their favorite platforms
  – Final production environments can be too scarce to pass around for development
  – Operational lifetimes can be decades on old platforms

• **Openness**
  – ITAR (International Traffic in Arms Regulations), EAR (Export Administration Regulations), and IP (Intellectual Property) are non-problems for existing Open code
    • Though Adaptations and changes for mission details can be controlled and limited
The Cost Question

• Cost of getting a product isn’t a big factor
• TCO (Total Cost of Ownership) is dominated by learning curve, testing, reviews, writing procedures, etc.
Confidence in the Future

- Developers like having the source code as a risk mitigator
- Managers like support contracts for the same reason
  - Glad to see companies offering these
- CMMI (Capability Maturity Model Integration) certification would help - puts a paper-trail on good practices like CM, test processes, etc.
  - Useless push-up or valuable scrub?
NASA’s Software Policy

• http://nодis.gsfc.nasa.gov/
  – Search for NPD 2820.1C
  – Some other good stuff there by searching for software

• Some relevant excerpts:
  – Require software providers (includes internal NASA providers) to have
    proven organizational capabilities and experience to deliver quality software
    on time, within budget, and within technical acceptability.
  – Require software providers to develop a plan to manage software
    throughout the program/project life cycle. This plan shall include the
    collection and reporting of actual software related expenditures at the
    project level by life cycle phases.
  – Release software in accordance with NPR 2210.1, External Release of
    NASA Software, consistent with law and applicable agreements, for
    commercial, industrial, educational, and governmental purposes.
And now some examples

- CLARAty
- Electra
  - MRO Electra
  - MSL ElectraLite
  - MSL TDS
  - Chandrayaan-1 M3
- CCA
- Supercomputing
- Others
CLARAty Project

• Coupled Layer Architecture for Robotic Autonomy
  – http://claraty.jpl.nasa.gov/

• Investigating robot visions, navigation, operator interfaces, simulation challenges, etc.

• Unified and reusable software that provides robotic functionality and simplifies the integration of new technologies on robotic platforms.

• Research tool designed for the development, validation, and maturation of various research technologies.
Interoperability: Software & Hardware

CAPABILITY: Navigation

Drivemaps
GESTALT
Obstacle Avoidance
MORPHIN
SRI Stereo
ARC Stereo
Stereovision
JPL_STEREO
Pose Estimation
MER_SAPP

CLARAty Reusable Software

Robot Adaptation

VxWorks
Linux
QNX

Sojourner Pose
FIDO 3DEKF
6D EKF

Ken Peters
AIE, Military OSS Conf, April 21, 2008
CLARAty: Key Challenges

- Robots have different physical characteristics
- Robots have different hardware architectures
- Contributions made by multiple institutions
- Advanced research requires a flexible framework
- Software must support various platforms
- Lack of common low-cost robotic platforms
- Software must be unrestricted and accessible (ITAR and IP)
- Software must integrate legacy code bases
CLARAty examples

• Rovers, including next-generation for Mars, are being tested between many institutions
  – JPL, ARC, CMU, U-Minnesota, etc.

• Test images are shared and access-controlled via OpenAFS filesystem
  – Latest pix from Spirit & Opportunity are used; AFS of course keeps the test set the same for everyone

• Code in AFS, CVS (Concurrent Versioning System)
  – YaM (Rapid Software Development Framework)

• Ames rover w/ laptop under solar panel - running linux and AFS
CLARAty videos

- [26 seconds] ROAMS (Rover Modeling and Simulation) SOOPS (Science Operations on Planetary Surfaces)
- [63 seconds] GESTALT (Grid-based Estimation of Surface Traversability Applied to Local Terrain) on FIDO
- [41 seconds] SCIP (Single Cycle Instrument Placement)
- [180 seconds] SMC Rocky 7 style rover with reconfigurable wheel/arm (from Shigeo Hirose - Japan)
Electra Radios

• NASA/JPL’s product line of Software-Defined Radios (SDR) and spin-offs in support of Mars Network concepts, and InterPlanetary Internet
Electra Radios, cont

• Provide UHF links in compliance with some CCSDS protocols
  – Consultative Committee for Space Data Systems
  – Proximity-1 (data link)
  – CFDP (file delivery)
  – http://www.ccsds.org/
  – http://www.ipnsig.org/
Electra Radios, cont

- Post-launch reconfigurability of protocol and signal processing functions
- Radio metric tracking for approach navigation, in situ surface positioning, and orbital rendezvous
- Timing services to support time synchronization of Mars exploration assets
Electra Dev Environment

- Code lives in a CVS repository stored in AFS, using kerberos authentication
  - Mostly C
  - Some assembly for trap handling
- Cross-compiled on linux for RTEMS on SPARCv7 target
- Built with gcc, make, libtools, etc.
- Linked with newlib
Electra: MRO

- NASA/JPL’s Mars Reconnaissance Orbiter
- Electra added as a payload for the Mars Network infrastructure, rather than used as the prime communications device
- Arrived at Mars in March, 2006
- Software fix for external radio interference, summer 2006
- Additional functionality will be needed for 2009 lander, MSL
MSL

- NASA/JPL’s Mars Science Laboratory
- Mars rover to launch in 2009
- Much larger than Sojourner or MER
MSL Electra-Lite

- Tighter mass/power constraints for lander than MRO
- Data throughput requirements drive new software radio function to adapt data rates during a communications pass by an orbiter
  - Easiest sequencing for either commanding or data return is single data rate, which needs margin
  - Adapting rates “fills in” lost bits under the optimum curve

Example Data Rate Change Performance
- 655 Mbits = Area Under the Black curve is Data Volume using a continuously variable data rate
- 521 Mbits = Area Under the Blue curve is Data Volume using a Root 2 Step Variable Data Rate
- 471 Mbits = Area Under the Red lines is Data Volume using a Factor of 2 Step Variable Data Rate
- 309 Mbits = Area Under the Green line is Data Volume returned using best Factor of 2 fixed data rate
MSL TDS

• Terminal Descent Sensor
• Landing RADAR
• Digital Electronics and software are Electra heritage
  • [111 seconds] EDL (Entry, Descent, and Landing)
Chandrayaan-1 M3

- ISRO’s (Indian Space Research Organisation) Chandrayaan-1 is India’s first moon mission, to launch in 2008
  - http://www.isro.org/chandrayaan-1/
- NASA is providing the Moon Mineralogy Mapper, a state-of-the-art imaging spectrometer instrument
- M3’s spacecraft interface is again Electra heritage
CCA

- NASA Constellation program’s CCA (C3I (Command, Control, Communications, and Information) Communications Adaptor)
- Internet RFCs to be implemented on range of “space routers” for:
  - CEV (Crew Exploration Vehicle)
  - CLV (Crew Launch Vehicle)
  - LSAM (Lunar Surface Access Module)
  - EVA suits, Habitat, Lunar Rover, Lunar orbiters
- What terrestrial uses need delay or disruption tolerant implementations we could re-use?
JPL Supercomputing

• http://sc.jpl.nasa.gov/
  – Aeronautical simulations, Lunar gravity map, Black Hole physics, electron collisions in plasmas - you know, stuff like that.

• Math libraries
  – LAPACK: A publically-available library (in source code) from Oak Ridge National Labs/University of Tennessee at Knoxville (http://www.netlib.org) which has become the standard for linear algebra solvers. Each of the manufacturers has created a version of this library optimized for their hardware.

• Beowulf clusters all over the place
Where FOSS isn’t found (yet?)

- Our business systems
  - E.g. timekeeping, benefits, staffing
  - The web-browser wars are alive and well.

- Management artifacts
  - E.g. presentation slides, schedules, budgets
  - OpenOffice sightings are rare

- Spreadsheet applications are becoming toolsets of their own
Ubiquitous FOSS

- Operating Systems, Systems Management
  - Rocks (cluster linux), Ganglia, amanda
- Software Management
  - Depot, Subversion, Trac, Bugzilla
- Communications
  - OpenSSH, Apache, Jabber, Firefox/Mozilla, Sendmail, Mailman, Procmail, CUPS, OpenOffice, wikis (various)

- Data Visualization
  - ImageMagick, GMT, MatPlotLib
- Compilers, languages, code checkers
  - SunStudio, splint, Doxygen, valgrind
  - Java, Perl (some JPL history there), Python, Ruby
- DB
  - MySQL
- ...And on and on
Fltops Dev/OPS/project

Third Party Software listing

a2ps-4.13 doxygen-1.4.2 gdk-pixbuf-0.22 ispell-3.2.06 libxml++-2.10.0 ogg_13.rt32_64 spin-4.1.2 vnc-3.3.3.x2
Acrobat7.0.1 dvdfq-1.5 gdome2-0.8.1 j2sdk1.4.2_10-j libxml2-2.5.12 open_inventor-2 qsqlite-3.2.8 W3C-2.8rev4
ActiveTcl8.4.11 eclipse-3.1.1 gettext-0.14.1 j2adkeel.3.1 libxml1t-1.16 OpenOffice.org1 startup-notify webmacro-classi
afa3.6.2.53 Edt confront3.0.7 gh-1.8.9-ppc jaf-1.0.2 linc-1.1.1 openssh-4.2pl struts-1.2.7 wget-1.5.3
ammozscripts_x elm2.5.8
antrl-2.7.1 exe emacse-21.3 gh-1.8.9-sol2 jai-1_2.2 java Abram-4.1 lynx1-2-8-5-16 m4-1.4 pango-1.4.0
apache-ant-1.6.1. enscript-1.6.1 gh-keys jakarta-tomcat- lynx2-8-5-16 openssl-0.9.7d osasm1.2159 sudo-1.6.8p9 wind-2.0-ppc
apache_1.3.29 EPak3.0.7 ghostscript-8.1 javacc-4.0 m4-1.4 pango-1.4.0
aspell-0.50.5 etjava6l ghostview-1.5 javamail-1.3.3_magicdraw-7.5f par-2.1.7 SWIG-1.3.4 wind-2.1-ppc
atk-1.6.0 ets_diagram-1 gimp-2.0.1 jdrl1.5.0_javav make-3.61beta1 perch-2.5.4 wind-2.1-ppc
autconfig-2.59 expat-1.95.7 gimp-print-4.2. jeditk2.3 makec-4.21 percp-3.6.0 wind-2.1-pcc
automake-1.8.4 expat-2.0.0 glib-2.4.0 jflex-1.4.1 marathon-0.9a tcl8.4.6_thread wxGTK-2.5
backpaxepress-2 expect-5.43 glibmm-2.4.2 jing-20010619 mc-4.5.53 p أقلاء-2.1.2 tcp_cwrappers_7. winMotif-2.2.7
tatik-1.5.1 FaultMeasuremen gimp-2.4.2 jnsp-2.4.2 jpdf-6rev1 penguin-2.0.0 tcsh-808
binutils-2.16.1 fetchmail-6.2.5 glu-4.0.0 jpe-3.1.1 metamail-2.7 plottutils-2.4.1 textutils-2.1 xalan-C_1_9_0
bison-2.1 fftw-3.0.1 glu proxy-1.3. jmsproxy-2.1.3 Meta-6.2.11 plotutils-2.4.1 textutils-2.1 xalan-j_2_4_D1
bint-2.42 fileutils-4.1 gprof-3.0.1 jpeg-6rev1 mozilla-1.7.12 pautilas1.17 thread-2.5.2 xchat-2.0.9
bpxro-5.0.4 filter-2.5.1 graphviz-2.6. jwawk-2.3.1 mpegdec-2.4.0 ptplot5.3 thunderbird-1.0 xcursor-1.0.2
bzip2-1.0.3 firefoot-1.0.7 grep-2.4.2 jugg2.0 mutt-1.4.4.11 PurifyPlus.2003 tidy-040106 xdoclet-1.2.1
cdctools-2.00.3 flex-2.5.4a groff-1.19 junict3.8.1 mysql-4.0.20 Pytho-2.4.2 tiff-3.7.1 xemace-2.14.18
cciam-7.26.1C1 fontconfig-2.2. gsoap-1.4 jython2.1 mysql-connector QO_Coverage-3.0 tiff-3.7.2 xerces-2.6.2
ccscope-15.5 fop-0.20.5 gtk+1.2.t10 python2-2.4.2 python-2.4.2 QtX11-free-3.3 ttx-8.0b3up1 xerces-C2_5_0
ccspice-60 forte_for_java-5. astart-2.2.0 tkforum-5.5.4 tkmm-2.4.2 less-382 readline-4.2a tk8.4.6_threads xerces-C2_6_0
ctags-5.5.4 freeglut-2.2.0 fop-0.20.5 gtk+1.2.10 gtksource-5.11 ncscales-3.4.4 tkcvs-7.1.1 xerces-C2_7_0_n
ctags-5.5.4 freeglut-2.2.0 fop-0.20.5 gtksource-5.11 ncscales-3.4.4 tkcvs-7.1.1 xerces-C2_7_0_n
ctags-5.5.4 freeglut-2.2.0 fop-0.20.5 gtksource-5.11 ncscales-3.4.4 tkcvs-7.1.1 xerces-C2_7_0_n
cup-0.10k freeingtype-2.15r gtkspell-2.2.0 libart_lgpl-2.3 ndiff-2.00 render-0.8 ttxdiff_4.0 xft-2.12
cup-0.10k freeingtype-2.15r gtkspell-2.2.0 libart_lgpl-2.3 ndiff-2.00 render-0.8 ttxdiff_4.0 xft-2.12
cvv-11.20.5s fop-0.20.5 freeingtype-2.15r gtkspell-2.2.0 libart_lgpl-2.3 ndiff-2.00 render-0.8 ttxdiff_4.0 xft-2.12
db-4.2.52.NC gawk-3.1.5 gzip-1.3.3 libghhttp-1.0.9 netbeans4.1 Rhapsody txml-2.2rev2 xpm-3.4K
dd-3.3.8 gec-2.95.3rev2 bprop_depth2 libghefifh-1.2. nedit-5.4 Rhapsody txml-2.2rev2 xpm-3.4K
ddcagnus-1.4.4 gcc-3.4.3.3 html2p-1.0b3 libhcon-1.9.2 nttf-7.5 raync-2.6.3 UConX-1.0 xv-3.10arev3
depot-5.13 gcc-3.4.3.3 libxml2-0.8.3 ObjectSpace-2.0 ruby-1.8.4 UConX-1.1 xxdiff-3.0.4
derby-10.1.1.1 gd-2.0.33 ImageMagick-6.2 libpng-1.2.5r2 ObjMan-62900 Sablot-1.0.1 UConX-3.21 zlib-1.2.3
dia-0.92 gdb-6.1 indent-2.2.9 libhseice++-2.03 octave-2.1.19 screen-4.02 UConX-6.2 zsh-4.2.0
diffutils-2.8.1 gdbm-1.8.3 InstallAnywhere libtool-1.5.20 octave-forge-20 sed-4.1.4 unzip-5.50
doors-7.1 gdbmprimitive- ipf-4.1.3 libuniscode-0.4 office52 slang-1.4.9 vim64
Google, Wikipedia, etc.

- OK, these are less about FOSS than about open and collaborative information exchange and problem solving.
- Does anyone look up mysterious error messages other places anymore?
- I (DJ) wrote a glossary for a NASA white paper on a project I was new to; most of the entries came from Wikipedia :-)

Sharing Lessons Learned

• http://llis.nasa.gov/ , Select “Topics”
  – Computers, Software, and lots of other non-software stuff that’s just neat to read
  – There are some pretty far-out gotchas written up
  – E.g. #1395: “...The design and code generation for the control and limit shutdown algorithms was relatively straightforward, but the challenge was to ensure it would all work correctly prior to firing up a developmental rocket engine for the first time...”
Challenge To Open Source Community

• Do as much of my job as possible, so I can do something else!
  – The more of your code we send to Mars, the better

• Think ahead of the cutting edge

• Round out the total package
  – Automated regression test suites with the code

• Brag about your users. Even in NASA, we don’t like to be the first, only, or biggest users

• Strength is in the people, the community. Conferences like this one help more than the developers

• THANK YOU for your hard work!