All Things Astrodynamic Standards Software

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Astrodynamic Standards (AS) Software

- **A software suite designed for warfighters and analysts that utilize JSpOC products**

- **Air Force Space Command (AFSPC) maintains and distributes**

- **Interoperable with JSpOC TLEs and VCMs**

- **Benefits**
  - **Ensure accuracy is not lost**

  - **Minimize risk and cost**

  - **Rapidly distribute improvements**

  - **Standardization**

- The Astrodynamic Support Workstation (ASW) is the operational system within the JSpOC that maintains the Special Perturbations (High Accuracy) Catalog
  - Produces Vector Covariance Messages (VCMs) that are shared with downstream users
  - Used for Conjunction Assessment, Maneuver Detection, etc..
  - Built as an operational system, and optimized for that environment
    - More difficult to extract algorithms for use in other applications
    - Designed for "real time" use; needs extensive environment setup
- Astrodynamic Standard Software is designed to be modular and able to be integrated in end users systems
  - Properly propagates VCMs and TLEs for use in applications
  - Applications designed to support needs of analytical community, they do not replicate all of the ASW functionality
  - Always "chasing" the ASW when upgrades occur

Customers of JSpOC Products

- **Aerospace**
- **DARPA**
- **MITRE**
- **MIT/LL**
- **Many Commercial Companies**
- **National Agencies**
  - **NASA**
  - **MDA**
  - **NASIC**
  - **NGA**
  - **NRO**
  - **NOAA**
  - **NSA**

- **US Air Force**
  - **AFIT**
  - **AFSPC (SBMCS, SCOPES, SSNAM etc.)**
  - **AFMC**
  - **AFRL**
  - **AFLCMC**
  - **ESC & SMC**
  - **SIDC**
  - **SSN Sensors (Dedicated, contribution, collateral)**
  - **AF Squadrons (13 SWS, 1SOS, 46 TS, 50 OSS, 6 SWS, 81 TSS)**
- **US Army Space & Missile Defense Cmd**
- **US STRATCOM**
- **US Navy**
  - **Naval Surface Warfare Center**
  - **NAVSOC**
  - **Research Laboratory**
  - **Space and Naval Warfare Systems**

JSpOC
(Space Control Center)
Operational Astrodynamic Algorithms

Data Products
(element sets & VCMs)

Customer WITHOUT interoperable JSpOC algorithm

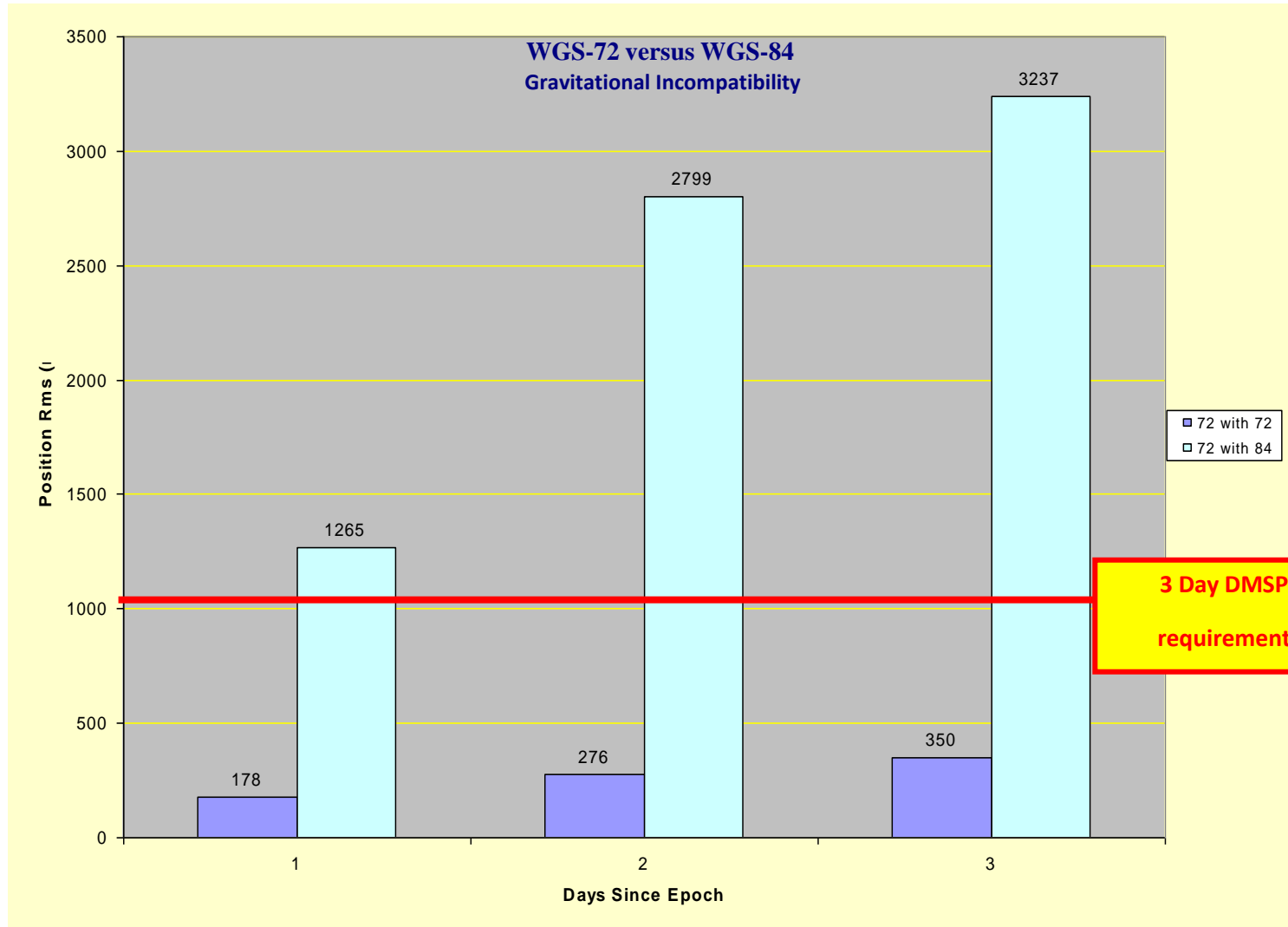**Customer WITH interoperable JSpOC algorithm**

LESS ACCURATE ANSWER

MOST ACCURATE ANSWER

Astrodynamic Accuracy

WGS-72 versus WGS-84
Gravitational Incompatibility

Position Rms — 3 Day DMSP requirement

Days Since Epoch

Legend: 72 with 72, 72 with 84

Values: 178, 1265, 276, 2799, 350, 3237

- **Because customers of JSpOC data products need to use the JSpOC algorithms…**
- **AFSPC provides, through AFSPCI 60-102, the JSpOC algorithms to new and upgraded space systems**
  - No need to re-develop the JSpOC algorithms and induce potential non-interoperability
  - Government numerical validation of the JSpOC algorithms has already been done
  - The government maintains and updates the JSpOC algorithms as needed
  - Enables rapid updates*…*

- **Need ability to make improvements to the JSpOC and distribute them rapidly throughout AFSPC and other users of JSpOC products**
    - In the past have been constrained because customers cannot easily change their algorithms
    - This can cause non-interoperability between the JSpOC and the customers
- **Need everyone on the same page**
    - Requires not just an algorithm standard but also a software standard
    - Similar analogy to Microsoft Office for Windows
    - Plug and play technology allows rapid updates with minimal cost

- **AOF (Area Over Flight)**

- **BatchDC (Batch Differential Correction)**

- **COMBO (Computation of Miss Between Orbits)**

- **FOV (Field of View)**

- **IOMOD (Initial Orbit Determination)**

- **LAMOD (Look Angles Generation)**

- **ROTAS (Report/Observation Association)**

- **SGP4 (Simplified General Perturbations #4)**

- **SP (Special Perturbations)**

- Laser Clearing House Deconfliction validation
- Evaluation of owner-operator ephemeris for JSpOC
- Defensive Space Control Studies
- SSN Sensor Performance Evaluations
- Modeling of SSN network architecture studies (SSNAM)
- DMSP propagation error assessment
- Supporting Numerical Validation of JSpOC mission software (ASW: SuperCombo output, CDM messages, etc.)
- Modeling and evaluating new sensor configurations/types
- Evaluating proposed improvements/changes to standard propagation theories (HASDM, EGP)

- **A library that can be easily integrated with any languages that support dll invocation**

- **A library that is easy to learn and implement to solve complicated astrodynamic problems**

- **A library that can provide upgrades without affecting the users' current code**

- **A library that can provide quick solutions to special or new requests**

Problems with Older AS Software

- **Only C/C++ can interface directly to the AS library. Other common programming languages cannot use the library**

- **Difficulty with learning and using the AS library because it required the use of large complicated data structures**

- **The old library worked exclusively with input/output text files which proved very inefficient**

- **The old library lacked of many commonly used astrodynamic utility functions**

- **All software packages are dependent at compiled time therefore it was very costly to make any changes to one of the packages**

- **Complete redesign of interfaces from V5.4**

- **The library has been modularized into many separate functional, easy to learn, easy to use DLLs (18 DLLs with ~400 APIs)**

- **Version 7 interface is simple because it uses only primitive data types. This allows the users to understand and be able to use it much faster**

- **Any programming language that supports dll invocation can call version 7 (C/C++, C#, VB.Net, Java/via JNA, Python, Matlab, Fortran)**

- **New APIs allow users to add/remove/update input data easily without the use of input text files**
  - **Can greatly reduce run-time**

- **The users now have direct access to output data**

- **Provides the users with many commonly used astrodynamic utility functions for direct use (coordinate & time transformations)**
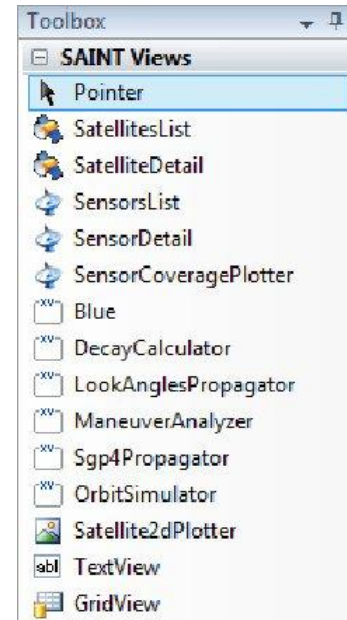
- **Version 7 is easy to maintain and enhance because of the clear separation between the interface and the internal implementation. This design allows A9 developers freedom to make any profound changes to the internal library with little impact to (interface exposed to) the current users**
- **Any new improvement to the library will benefit the end users by simply replacing the old version with the upgraded one**
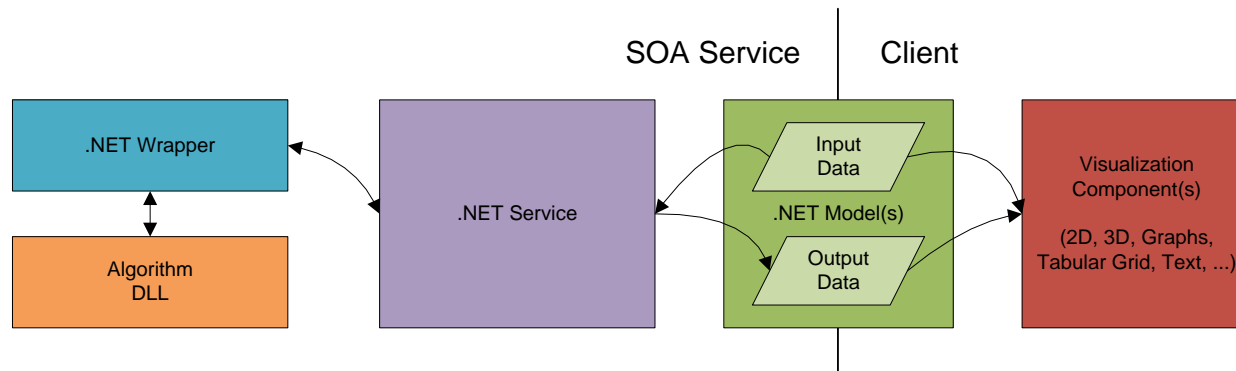- **Version 7 is designed to make future enhancements quickly and easily**

- Space Analysis Integration Toolkit (SAINT)
  - Collection of services and drag-and-drop components that can be used within the Visual Studio IDE to allow an analyst to develop space analysis applications in response to requests for quick turn studies.

    - Easy to use: Drag components on the IDE, set a few parameters and the application is ready to run.
    - Object-Oriented: Services represent the raw data arrays as objects with easily identifiable properties.
    - Services encapsulate some of the complexity involved initializing and combining the algorithm DLLs.

Toolbox

SAINT Views
- Pointer
- SatellitesList
- SatelliteDetail
- SensorsList
- SensorDetail
- SensorCoveragePlotter
- Blue
- DecayCalculator
- LookAnglesPropagator
- ManeuverAnalyzer
- Sgp4Propagator
- OrbitSimulator
- Satellite2dPlotter
- TextView
- GridView

- **SAINT delivers results for analysis because it is:**
  - FAST: Quick application development for analysis purposes
  - FRIENDLY: Very little programming effort involved.
  - FLEXIBLE: Integrates a modern GUI with any legacy compiled computer program
  - FOCUSED: Allows an analyst to focus on solving the problem, not the programming effort

SOA Service | Client

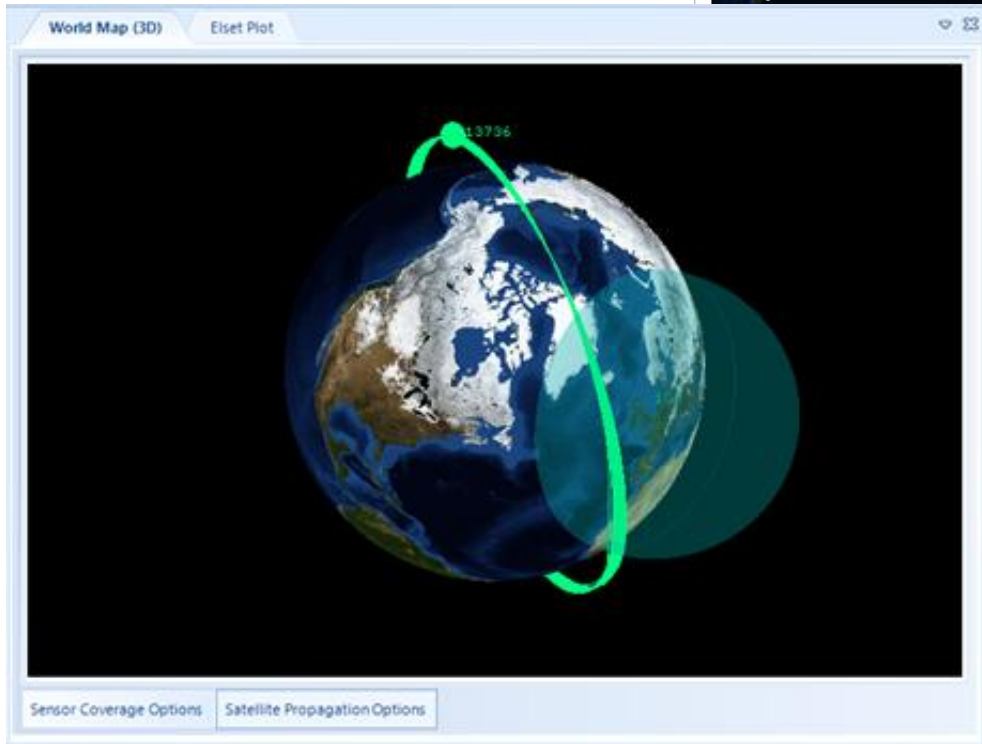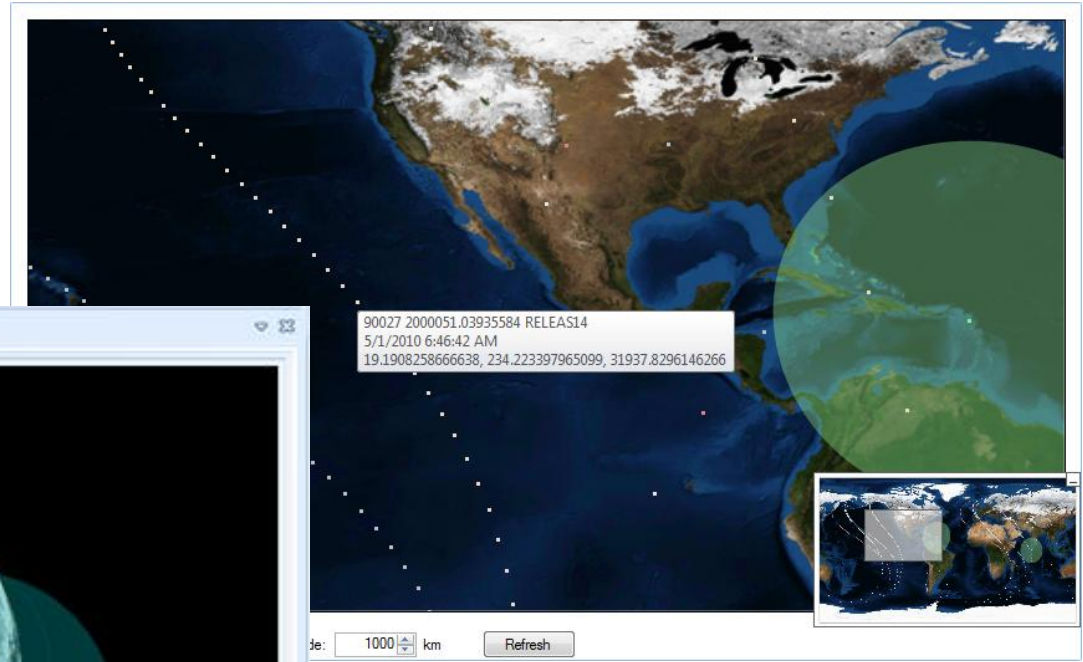.NET Wrapper

Algorithm DLL

.NET Service

Input Data

.NET Model(s)

Output Data

Visualization Component(s)

(2D, 3D, Graphs, Tabular Grid, Text, ...)

- SATRAK was built using SAINT
- Distributed in conjunction with Astrodynamic Standards
- SATRAK Modules
  - **SGP4**: Simplified General Perturbations #4, used to propagate satellites
  - **LAMOD**: Look Angle Module, used to determine sensor look angles
  - **SimOrb**: Used to simulate orbits
  - **Decay**: Used to calculate satellite decay and lifetime using King-Hele algorithm
  - **BLUE**: Bob's Launch Update Ensemble, used to update satellites to a new launch time. (Bob Morris)
  - **MANAL**: Maneuver Analysis, used to analyze satellite maneuvers
  - **Sensor Coverage**: Used to display sensor coverage on a 2D/3D map

- **SATRAK I/O**
  - **2D Map**
  - **3D Earth**

World Map (3D) Elset Plot

Sensor Coverage Options Satellite Propagation Options

90027 2000051.03935584 RELEAS14
5/1/2010 6:46:42 AM
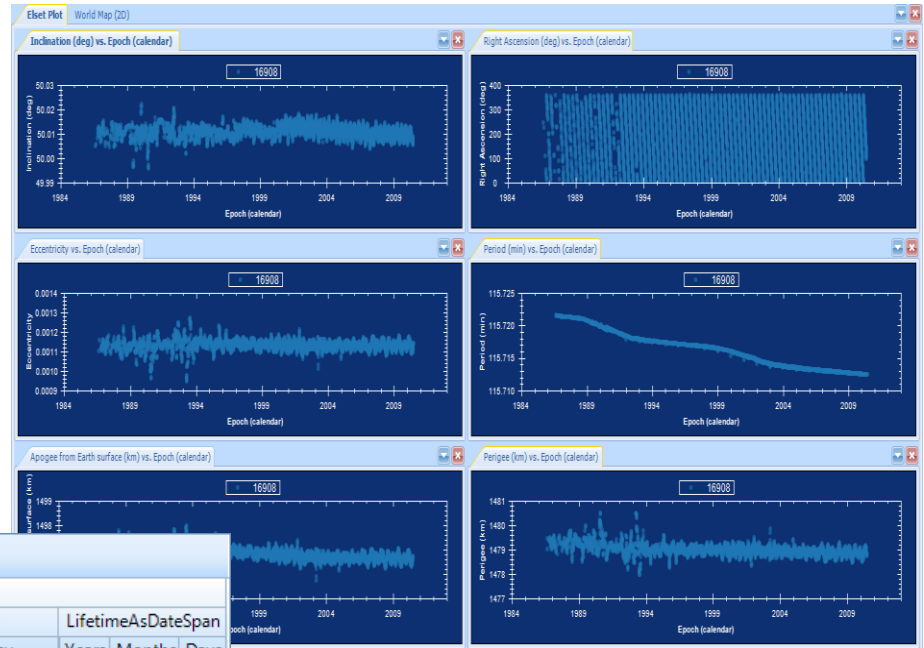19.1908258666638, 234.223397965099, 31937.8296146266

de: 1000 km Refresh

- **Real / Accelerated Time**
- **Time intervals**

- **Satellite Traces (SGP4)**
- **Sensor Coverage (LAMOD)**

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- ## **SATRAK I/O**
  - ### **Plotting**
    - **XY Graphs to plot any data (Element Sets, Propagations, …)**
    - **Add 3rd / 4th dimension by linking size / color**

- **Tabular Data**
  - **Export to Excel**
  - **Filter/sorting**
  - **Conditional formatting**

- **Complies with AFSPCI 33-105**
- **NIPRNet users (gov't and contractors) can request software using Space/Cyberspace Analysis Resource Portal**
  - **https://halfway.peterson.af.mil/SARP**
- **Other users can request using public site**
  - **http://www.afspc.af.mil/units/asda/index.asp**
- **Improvements to make the distribution easier are in progress**
  - **Replace AFSCI 33-105 with AFI 61-XXX**
  - **Separate Non-Export Controlled (documentation, sample drivers code, wrappers) from Export Controlled DLL and make Non-Export Controlled files available without going through approval process**

- **Starting 1 Oct 2017, only Version 7 will be supported**
  - **Upgrades to Version 7 will not include special SGI or SUN versions; will only support Windows/Linux – 32/64 bit**
- **SGP4, SP, LAMOD, COMBO - Windows and Linux Versions available now**
- **Rotas, IOMOD and OBS Windows versions recently released, Linux versions coming soon**
- **BatchDC DLL development in progress**
- **AOF, FOV ~ Available late 2015**
- **JMS will take over distribution after Inc. 2**

- **SARP Helpdesk Phone:**

    (719) 556-0936, DSN 834-0936

    (if no answer, call 719-598-7107, ext 110)

- **NIPRNet Email: SARPAdmins@us.af.mil**

BACKUP SLIDES

- Platforms:
  - Windows PC: Windows 7 32-bit/64 bit
  - Linux: Linux Red Hat 6.4 32-bit/64-bit
- Languages:
  - C/C++, C#, VB.Net, Java (via JNA), Python, Matlab, Fortran, etc.
- DLLs:
  - AstroFunc, Combo, DllMain, EnvConst, ExtEphem, Lamod, ObsOps, Obs, Rotas, SatState, Sensor,Sgp4Prop, SpProp, SpVec, TimeFunc, Tle, Vcm
- IDE/Compiler:
  - Windows PC: Visual Studio 2013\Intel Fortran Compiler XE v 14.0.2
  - Linux Red Hat V6.4: Intel Fortran Composer XE for Linux

- A dynamic link library (dll) or shared object (so) is a shared library of functions (procedures or subroutines). These functions are compiled, linked, and stored separately from the applications using them. Because of this separation, dll's can be shared and replaced easily without recompiling the applications that call them

- Each language has its strong and weak points

- No language can satisfy all application's requirements

- DLL is a way to bridge programming languages together.

Version 7 DLL Architecture