

Software Engineering Practices in Scientific Computing

and other exotic beasts Prof. Kochunas EECS 481 (W24)

Appendix C Step Functions, Delta Functions, and Other Exotic Beasts

I. INTRODUCTION





 $\Theta(x)$ is the unit "step function" introduced by Heaviside in his development of operational calculus (now known as integral transform analysis). One can perform numerous operations on $\Theta(x)$. In particular it can be integrated to yield the ramp function

$$\eta(x) = \int_{-\infty}^{x} dx' \Theta(x') = \begin{cases} 0, & x < 0 \\ x, & x > 0. \end{cases}$$
(C-2)

Let's try something a bit more unusual by taking the derivative of $\Theta(x)$. Clearly this is ridiculous, because this derivative, call it $\delta(x)$, is undefined at x=0 because $\Theta(x)$ is discontinuous at this point:

$$\delta(x) = \Theta'(x) = \lim_{\epsilon \to 0} \left[\frac{\Theta(x+\epsilon) - \Theta(x)}{\epsilon} \right] = \begin{cases} 0, & x \neq 0\\ \infty, & x = 0. \end{cases}$$
(C-3)

Nevertheless Dirac, Heaviside, and others have made very good use of this strange "function." To be more specific, the Dirac δ -function, $\delta(x)$, has the properties

$$\delta(x - x_0) = \begin{cases} 0, & x \neq x_0 \\ \infty, & x = x_0 \end{cases}, \quad \int_{-\infty}^{\infty} dx \, \delta(x - x_0) = 1.$$
 (C-4)



One-Slide Summary

- Prof. Kochunas's 5-steps to computational science software development
 - 1. Make it work
 - 2. Make it right
 - 3. Make it robust
 - 4. Make it fast
 - 5. Make it usable

(get it to run) (satisfy functional requirements) (get rid of bugs) (get answer quicker) (should not need PhD to use)



Outline

- Background
- Requirements
- Testing Quality Metrics
- Test Inputs and Oracles
- QA Processes
- Multi-Language Programs • Fun with VR (sort of)











Learning Objectives: by the end of today's lecture you should be able to...

1. (*value*) a lot of the course topics have immense practicality

2. (*value*) software development in computational science is probably more fun than working at a tech company



Background



A New Way of Looking at the World



3D Illusions by N.E. Thing Enterprises



Wait... why is a nuclear engineer here?

- Software from my PhD has
 - R&D 100 (2016)
 - NQA-1 Certified (2019)
 - Supported ~20 PhDs
- Also Developed graduate course "Methods and Practice of Scientific Computing" for MICDE in 2016



Consortium for the Advanced Simulation of LWRs (10 years and \$250M)









Oh by the way...

It operates like this:





And you'll need this:

• Largest open science computer in U.S.



but really for industry they want to use 1000 cores and deplete a cycle overnight





Michigan PArallel Characteristics based Transport

- MPACT did not exist at the outset of CASL, but grew out of the program.
- <u>To CASL</u>: MPACT is <u>the</u> deterministic neutronics code to solve the pin resolved power distribution throughout the reactor core.
 - Sits at the heart of the "core simulator" capability.
- <u>To UM</u>: MPACT is a research tool designed in a flexible way to facilitate PhD research in several areas
 - Transport methods, acceleration methods, parallel algorithms
 - Reactor Analysis and multi-physics numerical methods
 - As a teaching tool



The VERA Core Simulator



Spoiler alert! We did it!

at the heart of this is -







What is Computational Science and Engineering?

- CSE is a recently established multidisciplinary field of research and education
 - It lies at the intersection of mathematics, computer science, and science & engineering.
- As engineers how do we participate in CSE?
 - We have the applications & technology
 - We understand the physics governing our systems
 - But we may not know the latest math or how to effectively utilize computers to solve our problems





Pillars of Science

- Why so much focus on CSE?
- Traditional scientific and engineering method:
 - 1. Do theory or paper design
 - 2. Perform experiments, build prototypes, etc.
- Limitations
 - Too difficult—build a large wind tunnel
 - Too expensive—build a passenger jet and throw it away
 - Too dangerous—nuclear weapons
 - Too slow—climate change or astral evolution
- Computational science and engineering paradigm
 - 3. Use computers to *simulate and analyze* phenomenon





PhD's at U of M using MPACT

- Brendan Kochunas, 2013 A Hybrid Parallel Algorithm for the 3-D Method of Characteristics Solution of the Boltzmann Transport Equation on High Performance Compute Clusters
- Travis Trahan, 2014 An Asymptotic, Homogenized, Anisotropic, Multigroup Diffusion Approximation to the Neutron Transport Equation
- Blake Kelley, 2015 An Investigation of 2D/1D Approximations to the 3D Boltzmann Transport Equation
- Yuxuan Liu, 2015 A Full Core Resonance Self-shielding Method Accounting for Temperature-dependent Fuel Subregions and Resonance Interference
- Shane Stimpson, 2015 <u>An Azimuthal Fourier Moment-Based Axial SN</u> <u>Solver for the 2D/1D Scheme</u>
- Thomas Saller, 2015 <u>Asymptotic Homogenized SP2 Approximations to</u> the Neutron Transport Equation
- Ang Zhu, 2016 Transient Methods for Pin-Resolved Whole Core Transport
- Dan Walter, 2016 <u>A High Fidelity Multiphysics Framework for Modeling</u> <u>CRUD Deposition on PWR Fuel Rods</u>
- Mitchell Young, 2016 <u>Orthogonal-Mesh</u>, <u>3D Sn with Embedded 2-D</u> Method of Characteristics for Whole-Core, Pin-Resolved Reactor Analysis
- Michael Rose, 2017 Multiphysics Simulation of Fission Gas Production and Release in Light Water Reactor Fuel

- Aaron Graham, 2017 Subgrid Methods for Resolving Axial Heterogeneity in Planar Synthesis Solutions for the Boltzmann Transport Equation
- Benjamin Yee, 2018 A Multilevel in Space and Energy Solver for Multigroup Diffusion and Coarse Mesh Finite Difference Eigenvalue Problems
- Michael Jarrett, 2018 <u>A 2D/1D Neutron Transport Method with Improved</u> <u>Angular Coupling</u>
- Jipu Wang, 2019 Application of the Method of Manufactured Solutions to Verify the Method of Characteristics for Reactor Analysis
- Andrew Fitzgerald, 2019 Parallel 3-D Method of Characteristics with Linear Source and Advanced Transverse Integration
- Andrew Gerlach, 2020 Adaptive Time Stepping for Transport Solution with the α -Eigenvalue
- Qicang Shen, 2021 <u>Robust and Efficient Methods in Transient Whole-Core Neutron Transport Calculations</u>
- Zackary Dodson, 2021 <u>Linear Diffusion Acceleration for Neutron</u> <u>Transport Problems</u>
- Nicholas Herring, 2022 <u>The Legendre Polynomial Axial Expansion</u> <u>Method</u>
- Nickolas Adamowicz, 2022 <u>The NILO-CMFD Method for Iteratively</u> <u>Solving Coupled Neutron Transport-Thermal Hydraulics Problems</u>



Computational Science Requirements are more than functional





Requirements: One-Slide Summary

- Requirements articulate the relationship and interface between a desired system and its environment. This includes both what is (or is expected) and what should be.
- We distinguish between functional and quality (or nonfunctional) requirements. Both should be stated in measurable ways.
- Requirements can describe variables, inputs, and outputs, and assumptions between them.
- We distinguish between informal statements and verifiable requirements.



High-Level Requirements (Roadmap)

Date Completed	Benchmark Problem Description
09/2012	• #1 2D HZP Pin Cell
12/2012	#2 2D HZP Lattice
~5/2013	• #3 3D HZP Assembly
~7/2013	#4 HZP 3x3 Assembly CRD Worth
11/2013	• #5 Physical Reactor Zero Power Physics Tests (ZPPT)
11/2013	#6 HFP BOL Assembly
4/2014	#7 HFP BOC Physical Reactor w/ Xenon
7/2014	#8 Physical Reactor Startup Flux Maps
9/2014	#9 Physical Reactor Depletion
2/2015	• #10 Physical Reactor Refueling

Application drives development

A cycle depletion on < 1000 cores, overnight



Functional

Requirements

• What do we notice?

 What's good/bad about these requirements

Fuel Shuffle File Requirements

- Must implement the "VERAIn Specification for LWR Core Shuffling and Jump-in" specifications below for Cartesian grid LWRs. Specifically:
 - a. Must be able to process the specified VERA input options as stated
 - Must be able to read in one or more (depending on mode) properly generated VERA restart files and use them to begin a calculation
 - c. Must be able to produce the specified restart file at the end of a VERA state calculation
- Must be able to write, read, and shuffle (where applicable) any reactor component of any reactor type for which tracking irradiation may be of interest:
 - a. Fuel rods/assemblies
 - b. Inserts
 - c. Control rods/blades
 - d. Nozzles
 - e. Core plates
 - f. Grids
 - g. Baffle/reflector
 - h. Reactor vessel
 - i. Composite blocks
 - j. Fuel pebbles
 - k. Molten salt compositions
 - I. Solid moderator components (e.g. graphite blocks)
- 3. Must work for all reactor types
- 4. Must be able to write, read, and shuffle (when appropriate) the following information:
 - a. Geometry information: Core layout, axial mesh, thermal expansion parameters
 - b. Feedback and post operation data
 - i. Component-specific data (e.g. vessel fluence from SHIFT)
 - ii. Pin-wise data (CRUD/corrosion data)
 - iii. Any other feedback/post operation data that could be required
 - c. State data such as power history and reactor state data from the end of the previous calculation (e.g. control rod positions, boron concentration, etc.)
- 5. Must support reconstituted rods for solid-fueled reactors when performing restarts or shuffles
- 6. Must be able to restart using different thermal expansion temperatures than were used to

Need to talk to about the exact requirements for this (I think I have a good guess but I'll make sure with him), then the developers can determine what information to write to the file to accomplish that



Quality Requirements

Input Example: Write and Read a Restart File



- 7. Should be able to optionally write & read depletion isotopes in addition to transport isotopes
- 8. Must support various levels of HDF5 compression
- 9. Must support axial remeshing on an assembly-by-assembly basis
- 10. Must support radial remeshing on a pin-by-pin basis



Testing Quality Metrics





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QA and Testing: One-Slide Summary

- Quality Assurance maintains desired product properties through process choices.
- Testing involves running the program and inspecting its results or behavior. It is the dominant approach to software quality assurance. There are numerous methods of testing, such as regression testing, unit testing, and integration testing.
- Mocking uses simple replacement functionality to test difficult, expensive, or unavailable modules or features.

(special thanks to James Perretta for material)



Test Quality Metrics: One-Slide Summary

- Test suite quality metrics help us decide which suite to use. Line coverage, the fraction of lines visited when running a suite, is simple but gives limited confidence.
- Branch coverage, which requires both true and false values for conditions, is richer (incorporating data values indirectly).
- Mutation analysis measures the fraction of seeded defects detected by a suite; it is expensive but effective.
- Beta and A/B testing involve real users and their experiences.



Test and Source Code Metrics

- Code Coverage (by line)
 - Utils: 91.6%
 - Reactor: 84.0%
 - CoreSolvers: 84.1%
 - MOC: 70.3%
 - CMFD: 28.9%
 - XS: 73.5%
 - UI: 57.9%



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Integration and Regression Testing

Quarter
Full
Assembly Gap
Nozzles
Core Plates
Reflector
Baffle
Inserts
Control Rods
Detector
Nominal Spacers
Above/below fuel
IFM
Explicit

	2D PU					
	2D Pn					
	2D/1D NEM					
	2D/1D SP3					
	CMFD 1g					
	CMFD MG					
	Search keff					
	Search boron					
	Search rod					
vers	Multistate					
Sol	Depletion native					
	Depletion origen					
	Shuffle rotational					
	Shuffle mirror					
	InternalTH					
	CTF					
	Eq Xe/Sm					
	Subgroup					
	ESSM					

Cusping



Figure 2.4 MPACT Regression Suite Matrix [Collins, 2015a].

Geometry



Regression Test Suite Acceptance





Validation Testing (Test against reality)





Map Functional Requirements to Validation Data

	Validation Activities																															
Operating Power Plants							Critical Experiments								F	Post-Irradiation Exams			CE Monte Carlo			0										
Watts Bar	BEAVRS	Catawba	McGuire	Westinghouse 3-Loop	Krsko	B&W-Type	CE-Type	B&W	Helstrand	KRITZ	DIMPLE	VENUS	IPEN/MB-01	RPI	SPERT III	Strawbridge & Barry	Saxton	CREOLE	EPICURE	CAMELEON	CROCUS	JAERITCA	ICSBEP	Catawba MOX LTAs	Three Mile Island	MALIBU	Robinson	Calvert Cliffs	Pin-by-Pin Fission Rates	Intra-Pin Distributions	Depleted Isot opics	Misc. Applications



Map Functional Requirements Validation Data

Capabilities					
PWR Types			\cap	valid	aalan Activities
Westinghouse 4-Loop				Operating Power Plants Critical E	eperfinents Post-irradiation Exams CE Monte Carl
Westinghouse 3-Loop				Annual and an annual and an annual annua	avelatige & i ton control of the con
Westinghouse 2-Loop			Opabilities WR Types Westinghouse 4-Loop Westinghouse 3-Loop	x x x x x x x x x x x x x x x x x x x	x x x x
Babcock & Wilcox (B&W)			Westinghouse 2-Loop Babcock & Wilcox (B&W) Combustion Engineering (CE)		
Combustion Engineering (CE)			17x17 16x16 16x16 CE	X X X X X X X X X X X X X X X X X X X	X X X X X X X X X X X X X X X X X X X
Fuel Assembly Types			15x15 15x15 B&W 14x14 CE Mixed Oxide Fuel (MOX)		x x x x x x x x x x x x x x x x x x x
17x17	Physics Components		Burnable Poison Types Pyrex IFBA WABA	x x x x x x x x x x x x x x x x x	x x x x x x x x x x x x x x x x x x x
16x16	Neutron Transport		Solid B4C-AL2O3 Gadolinia Erbia		x x x x x
16x16 CE	Gamma Transport	↓ ←	AIC BIC Hybrid	x x x x x x x x x x x x x x x x x x x x x x x x	X X X X X X X
15x15	Coolant Density Feedback		Gray Hafnium Incore Instrument Types Moveable		X X X
15x15 B&W	Fuel Temperature Feedback		Fixed Radial Reflector Types This Baffle Thick (Heavy) Shroud	x x x x x x x x x x x x x	X X X X
14x14 CE	Isotopic Depletion		Physics Components Neutron Transport Gamma Transport	x x x x x x x x x x x x x x x x x x x	* * * * * * * * * * * * * * * * *
Mixed Oxide Fuel (MOX)	Xenon Concentration		Fuel Temperature Feedback Isotopic Depletion Xenon Concentration	x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x	x x x x x x x x x x x x x x x x x x x
Burnable Poison Types	Shutdown Decay		Shutdown Decay Physics Besults Reactivity Assembly Power Distribution	x x x x x x x x x x x x x x x x x x x	x x x x x x x x x x x x x x x x x x x
Pyrex			Pin Power Distribution Intra-Pin Power Distribution Pin Burnup Distribution Intra-Pin Burnup Distribution		x x
IFBA			Incore Instrumentation Response Excore Instrumentation Response Control Rod Worth	X X <td></td>	
WABA			mperature coefficient		
Solid B4C-AL2O3					
Gadolinia			\smile		
Erbia					



We still have bugs and get the wrong answer



Test Inputs, Oracles, and Generation

REMAINS OF AXIS PUB, SUDDEN MOUNTAINS, DIMENSION OF KNACKITUDE LEARNING THE KNACK OF TRAVEL BETWEEN LEVELS OF REALITY REQUIRES US OKAY. TO LOOK BEYOND OUR NATURE, THERE TO FIND 50, THE ULTIMATE TRUTH OF OUR UN-NATURE. DO THAT. NO, I'M SORRY. YOU NEED 301 YOU KNOW I THOUGHT THIS AS A PREREQ. HOW? THE USUAL WAS AN INTRO ARE YOU AN WAY CLASS? UNDERGRAD? 0 \mathbf{O} amultiverse.com SCENES FROM & MULLIVERSE : 309 04, 2010 @2010 JONALHAN ROSENBERS, COMPLAINES: JON@AMULLIVERSE.COM



Inputs & Oracles: One-Slide Summary

- Formally, a test case consists of an input (data), an oracle (output), and a comparator.
- Test inputs determine the behavior of the program. Highcoverage inputs can be generated automatically through path enumeration, path predicates, and mathematical constraint solving.
- Test oracles correspond to what the program should do. Generating them is an expensive problem; but it can be done automatically (sort of) through invariants and mutation.
- Test suite minimization finds the smallest subset of tests that meet a coverage goal.



A Taxonomy of Testing (If its not tested, its not a supported feature

- Unit Testing Test individual units of program in isolation
 - Should run very fast: < 1 second (a couple seconds is ok)
- Integral Testing Testing program components together
 - Should run fast: < 1 minute (a couple minutes is ok)
- Regression Testing Test whole program for changes in program output
 - Should run fast: < 1 minute (a couple minutes is ok)
- Verification Testing Test that you are "doing things right"
 - Can happen at unit or integral or regression level. Comparison analytic solutions or manufactured solutions.
- Validation Testing Whole program testing "doing the right thing"; simulating reality, comparison to experiment.
 - May be long running: minutes to hours
- *Memory Testing* Expensive testing that does detailed memory simulations to detect errors (valgrind)
- Coverage Testing Figure out how much of your source code is actually covered by testing
- Portability Testing test on different platforms and with different compilers



Test input path testing

Change input settings





Verification and Validation

- <u>Model verification</u>: substantiation that a computerized model represents a conceptual model within specified limits of accuracy.
- <u>Model validation</u>: substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model.





V&V In the Context of SQA





Simple Test Example

- Symmetry
 - Define a problem with geometry and boundary conditions symmetric about a plane
 - Can also look at periodic problems
- Rotational Invariance
 - Similar to the above except change coordinates
- Conservation (perform global integration)
 - · of energy in heat transfer
 - · of mass or momentum in fluid flow









What CSE typically does not do...

- Automatic Test Generation
 - Inputs and oracles
- Mutation analysis
- Path Coverage
- Test Suite Minimization





Trivia Break





Trivia: Physicist

 This Dutch-American physicist is credited with jointly proposing the concept of electron spin at 23. He was the editor-in-chief of the leading physics journal Physical Review Letters, received the National Medal of Science, and has a named collection of Egyptian antiquities





Trivia: Great Minds

- These photo features
 - Samuel Goudsmit
 - Werner Heisenberg
 - Enrico Fermi
- It was taken at one of the world's pre-eminent physics summer schools in 1939
- Where was it taken?





Trivia: Manhattan Project

- These women operated this type of machine who's inventor received a Nobel prize (in 1939) for its invention.
- Despite the women not being told exactly what it was they were operating. They engaged in a week long competition with male scientists (mostly PhDs) to see who could produce more product and outperformed their male colleagues.
- Their service was crucial to the production of "tube alloy" for "Little Boy"





QA Processes





Inputs & Oracles: One-Slide Summary

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Ideal Maturity of Software Quality Metrics



Figure 1. "Example of the more typical variability in key quality metrics in a typical CSE software development process." From R. Bartlett, et al., "TriBITS Lifecycle Model Version 1.0," SAND2012-0561, (2012)



Real Software Quality Metrics



Figure 6. "Example of the more typical variability in key quality metrics in a typical CSE software development process." From R. Bartlett, et al., "TriBITS Lifecycle Model Version 1.0," SAND2012-0561, (2012)



The MPACT Dev Process

Iterative development Process





NQA-1 Program

- Sets QA requirements for program
- Each release has
 - Software Management Plan
 - User Manual
 - Theory Manual
 - Verification and Validation Manual
 - Programmer Manual
 - Software Test Plan Requirements and Test Report



MPACT Software Test Plan, Requirements, and Test Report



CONTENTS

TA	ABLES v								
1	Purpose and Scope								
2	Testing Procedure								
	2.1 Computer Program Tested								
	2.2 Test Equipment Calibration								
	2.3 Date of Test								
	2.4 Data Recorder								
	2.5 Simulation Models Used								
	2.6 Test Problems								
	2.7 Results and Acceptability								
	2.8 Action Taken in Connection with Noted Deviations								
3	Applicable Standards and Procedures								
4	Required Records								
	4.1 CDash Test Results								
	4.2 Requirements Traceability Matrix								
Aj	Appendix A MPACT Test Report								
A	ppendix B Requirements and Test Traceability Matrix								

		*
848	MPACT_exe_testVerify_shuffle_oddpin_rotation-y_rot2	Completed Passed
849	MPACT_exe_testVerify_shuffle_oddpin_rotation-y_rot3	Completed Passed
850	MPACT_exe_testVerify_shuffle_oddpin_unfold_mir	Completed Passed

Traceability

	Requirement Description
Pog ID	Test Name
Keq. ID	Test Input
	Additional Info
	MPACT shall compute solutions to a 3-D mutliassembly model with control rod
1	movement.
1	
	MPACT_exe/tests/regression_tests/mini_core/4-mini_apsr.inp
	MPACT shall compute solutions to a shuffle of an evenpin lattice, mirrored across
2	the x-axis, with 0 quarter rotations.
2	
	MPACT exe/tests/regression tests/solution verification/xml input/
	shuffle symmetry/evenpin mirror-x rot0.inp
	MPACT shall compute solutions to a shuffle of an evenpin lattice, mirrored across
	the x-axis, with 1 quarter rotations.
3	
	MPACT exe/tests/regression tests/solution verification/xml input/
	shuffle symmetry/evenpin mirror-x rot1.inp
	MPACT shall compute solutions to a shuffle of an evenpin lattice, mirrored across
	the x-axis, with 2 quarter rotations.
4	
	MPACT exe/tests/regression tests/solution verification/xml input/
	shuffle symmetry/evenpin mirror-x rot2.inp
	MPACT shall compute solutions to a shuffle of an evenpin lattice, mirrored across
-	the x-axis, with 3 quarter rotations.
5	
	MPACT exe/tests/regression tests/solution verification/xml input/
	shuffle symmetry/evenpin mirror-x rot3.inp



Defect Reporting: One-Slide Summary

- A software defect report includes information and communications related to addressing a software issue.
- Defect reports have many components
- Defect reports are subject to triage based on severity and priority information.
- Defect reports have a lifecycle that is complicated and non-linear with multiple possible resolutions.



Defect Reporting and Triage

FTWARE PROBLEM REPOR	:т	Р	roblem Report ID: 2020-0	017-0
e Received by VSM: March 24				
ginator/Originating Organization:	EPRI			
TWARE PRODUCT: MPACT		RELEASE/V	ERSION #: VERA 4.1RC	22
DBLEM REPORT TYPE			ATTACHMENTS: 🗖 Yes	□ No
Coding Error 🛛 🗖 Document	ation		If yes, list attachn	nents:
Data Library Error 🛛 🗖 Build Issue	•			
Other (specify)				
or Reporting Category: 🗖 Major	■ Medium	inor	DEM A/SM Evoluation of	rror
or Reporting Category: 🗖 Major is for Error Categorization: 🗖 Con EVANT KANBAN TICKET(S): 6347	■ Medium ☑ Mi veyed by User/Origi	inor nator 🛛	PSM/VSM Evaluation of I	Error
or Reporting Category: 🗖 Major is for Error Categorization: 🗖 Con EVANT KANBAN TICKET(S): 6347 Item	■ Medium	inor nator 🛛	PSM/VSM Evaluation of I	Error
or Reporting Category: 🗖 Major is for Error Categorization: 🗖 Con EVANT KANBAN TICKET(S): 6347 Item Ite	Medium Minima M	inor nator Des te Calculations S	PSM/VSM Evaluation of I cription egfault with Transient Mi	Error
or Reporting Category: Major is for Error Categorization: Con EVANT KANBAN TICKET(S): 6347 Item Ite Ita Library	Medium Mi Veyed by User/Origi Steady-Stat Options Unrelated	nator and a state of the state	PSM/VSM Evaluation of I cription egfault with Transient MI 's	Error PACT

A user reported the error

How was the error identified?

When does the error occur?

Potential impact of error	If users do not realize these cards are present in the input block, then their case will segfault during input processing.
Frequency/likelihood of error occurring	This will happen anytime the aforementioned input cards are used in a steady-state calculation.
How can users determine if error affects their calculations?	The user can review the MPACT block of their input for presence of the "prompt" or "accel" card.
What action should users take if error affects them?	Remove or comment out the "prompt" or "accel" carc from the input.
Is correction to code/data available?	The code has been modified to ignore these options when present in a steady-state input.
How to obtain/install correction	The fix for this will be available in VERA 4.2.
Additional Comments:	

variable that is already deallocated.

The error occurs when a user includes either the

"prompt" or "accel" card in the MPACT block of their VERA input, but intends to run a steady state calculation. When MPACT begins processing the XML input it seafaults when attempting to deallocate a



Scientific Computing is inherently multi-lingual





Multi-language Projects: One-Slide Summary

- Many modern software projects involve code written in multiple languages. This can involve a common bytecode or C native method interfaces.
- Native code interfaces can be understood in terms of (1) data layout and (2) special common functions to manipulate managed data.
- Almost all aspects of software engineering are impacted in multi-language projects.



xSDK – eXascale Software Development Kit

xSDK Version 0.8.0: November 2022













History of the Ford Nuclear Reactor





Founding Monday, May 17th, 1948



		Latest Deadline in the State		
PECIAL ESSUE		ANN ARBOR, MICHIGAN, MONDAY, MAY 17, 1948		PRICE FIVE CENTS
TC	M	RESEARCH CEI	NTE	R
T	O B	E 'U' WAR MEN	AOR	IAL
nning	g, Study	Harnessed for Humanity	Phoenix	Plan
k of	Project		To Bene	fit Man
and Half on al Studen	of Work Follows t Legislature Idea there suggest the a year and	and water first and a state	Huge Program Peaceful Appli	n Will Probe ication of Atom
And a "Description" of the LE, 1946. That is provide the transformer offic composition offic composition and for some others, alty-student War Ma	warch and effects to hardle lags we memorial originated with eloca- difi the Sistem Lephatore were intraced and had torriarive plane the University Board of Reprote- mental Committee in September, "The		An all-out offensive to cors- into a living and lasting force fo launched today by the Universi and faculty members who died President Alexander G. R linhment of the "Phoenix Projec	ert the nightmare of Naganaki or the betterment of man was ty in memory of its students in World War H. obven announced the estab- att world's first research
rial Is ed With	Association request that the war- nergional de samething more there is more sound of disease to com- pose or where would be seen in- posed. The there is an atomic research entire first comption required within first comption required		militatin devoted exclusively to humanitarian applications of arc Named the Phoenix Projet of a rave as from the adue and a sitzy War Meanmal is fromtout in trightful Manifestua Project. It will free bit areas."	exploiting the poachal and anic corregy. act to symbolize the creation struction of the oil. He there- mest contrast to the hand but I be a "living, timeles, creative
Support, s of Aid	New York publisher and one time Deliverity student. As a prioris to the University's war don't be organized a wall project designed to make atomic seeing the door within than the master of stat-	Larre We all	Beacher beth the official up- proved of the U. S. Abstate Theory Contribution and a provision of actual Publical Protection Project will be compared of from meeting parts.	Project Will Aid Research
e and applierence Project in "Inte- be Instantis" For white of everyone in its evolution y more monitor age, ther for peacefine- hies altered patte-	ting He saled it 's constructive contrins to the pathological tog- created in the saints of the provide of the work by the Alone Bent's advect." The idea was endicated	AND A DESCRIPTION	L) A MENORAL ROTTN- TA to be constructed on easi- put as a magnet to drive in- pulser the prest admins of the age interested in cerup possible homomilarian, physical and in- tellectual phase of alaquie de- velopment.	War Memorial Is Functional
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ar Memorial Cien- Smith, New York, in-lime University ine Mail 616 pro- bition for the con- bition for the con- vision for the con- section. University activity, approval	In Polorary of 10% year Dess Reich Walter, Dean Rahft Bar- yer and Dr. Prod Redges generated beiere the Atomic Energy Com- mutant Washington, D.C. to explain the proposed procetime above mention corrier. After a compact Rahft is the ne-	A STANK	4.) PUBLISHING of all data compiled and classified in the Planesis Project at regular in- ternals will keep such alsons scientist and researcher throughout like write up to data at all times in the findings of the other securities for the	messared in terms of human welfare." The Phonoix Project is to be metical inverse well as him- nerical in recommens that there we at present thousands of wit- mans sentered all over the world welfare independently on non-
thene concerning rapidly controlled all Europy Con- ropoul had fittle that hurdle polynamen Carroll Washington ap-	terms expital they outlined the mote proposal is the highest at- omic affronts. They reaso out of that instoric meeting with the solid toximing of the Atomic Ener- sity Commission which appended the more. On March 26 the Office of Ner-	Party Care	nhemic key to prose, The War Mirneyial's sharmori- renginasis will be entered isorby to motivities and other human- indum streams instand of or power and engineering, theislogr, philmosophy and other atoms agt	alori promo of intra-solucitor atoms research. If their work and be conditioned, musiles and be anothered atfinitely factor. The Pesiect will function as a charring house for these seal- breat down. It will closelly, file and publish house or the anore
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end in Due develop- not were stationally	They has promised " to yead- tr support in any way possible to- surd the organization of such an institute."	DYNAMIC REACTION: Students Assure Phoenix Backing	take up the threads of alongi- remarch at the point where existing apencies have slopped, attituing isotopes manufactured	perific projects to atomic re- march and mindrede the early with Diagotial assistance to mi- minute throughout the country. "The atomic booth was develop-
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ther, that ing the hare studends part of the War lifter.	Burdly a seen before this off- ial amoincommt a group of indent backers was called in for the initial campus announcement of the project Septementing all taking campus expandentions, the	em Poster and already draw have made weaked personnels and already draw have made weaked personnels and already draw have the structure of the structure of	until next fail, an administrator will be announced within a few product of doministrator for the Product Ryopart will be accepted from new oc. The desired basis of the first	Recogniting that the abandor app will affect every phase of man's tile, the Phornix Project will not Runit its activities (a physical sciences.
campta: worr project, was immediate withing enough	sources 2040/rm 141d plana to owing Usely groups behand the stonit measurily emfort Plans were then mode in give the Planary Project the whitest possible publicity. The Early was	Namenal to defense the horizont is an intermediate the product of	versity is supresed to spear- bend the drive for funds with the active avoidance of the 125,600 abased. Studeets will spread word of	Leaders is philosophy, accordingly and all the sovied sciences will be invided to form a void "acade- re of atimizary" to many that reactions about research will nove abane overly in all faile.
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A permanent monument to University dead of World War II, the

completed Phoenix Memorial Laboratory will look like this.

COLLEGE OF ENGINEERING & RADIOLOGICAL SCIENCES

The cubical windowless area at the right represents the student offices nuclear reactor







September 1954

Phoenix Memorial Lab (Ford Nuclear Reactor)

Cooley Building (My office)







Phoenix Memorial Lab (Ford Nuclear Reactor)

Cooley Building (My office)

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Ford Nuclear Reactor



- The Ford Nuclear Reactor (FNR) was a research reactor that operated at U of M from September 1957.
- FNR was used to explore peaceful uses of nuclear energy for the wellbeing and advancement of humanity.
- Unfortunately, FNR was permanently shut down in July 2003 and eventually decommissioned due to the prohibitively high cost of maintenance and operation.





Figure 1. Color photograph of the FNR facility from the Detroit News Sunday Pictorial, Sept. 13, 1959



Figure 2. The FNR building and adjacent Phoenix Memorial Lab



Figure 3. Professors in the glow of the reactor plotting their next student assignments





Figure 4. Photograph of a reactor operator at the FNR control panel



Figure 5. Photograph of FNR reactor pool construction 60



The first visit to the FNR made by a school group of Burns Park sixth graders taught by Mrs. Betty Melhuish





Mrs. David Weyant demonstrates the versatility of the manipulator by picking up a book of matches, taking one match out, lighting it and then lighting a cigarette for Prof. Ralph A. Sawyer head of the the Phoenix Project







4/3/2024





2016





Filling in the FNR Pool with Concrete

1950's

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Cutting Windows in the Reactor Building



Let there be light! And so the students shall have windows.



2016

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Timeline of VFNR Development







Project Phase 1: CAD Model Development







The Map is not the Territory



Scale Drawing of the Reactor Floor

Cross section of a CAD model of the FNR building







Project Phase 4: Enhanced Immersiveness







Project Phase 4: Enhanced Immersiveness









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Questions?





Navigate to: <u>https://innovationpartnerships.umich.edu/available-inventions/</u>
 Search for Virtual Ford Nuclear Reactor