



Thunderhead Engineering – Continuing the Rand Hall Ethos

Daniel Swenson
Brian Hardeman

Old Ingraffea Pictures

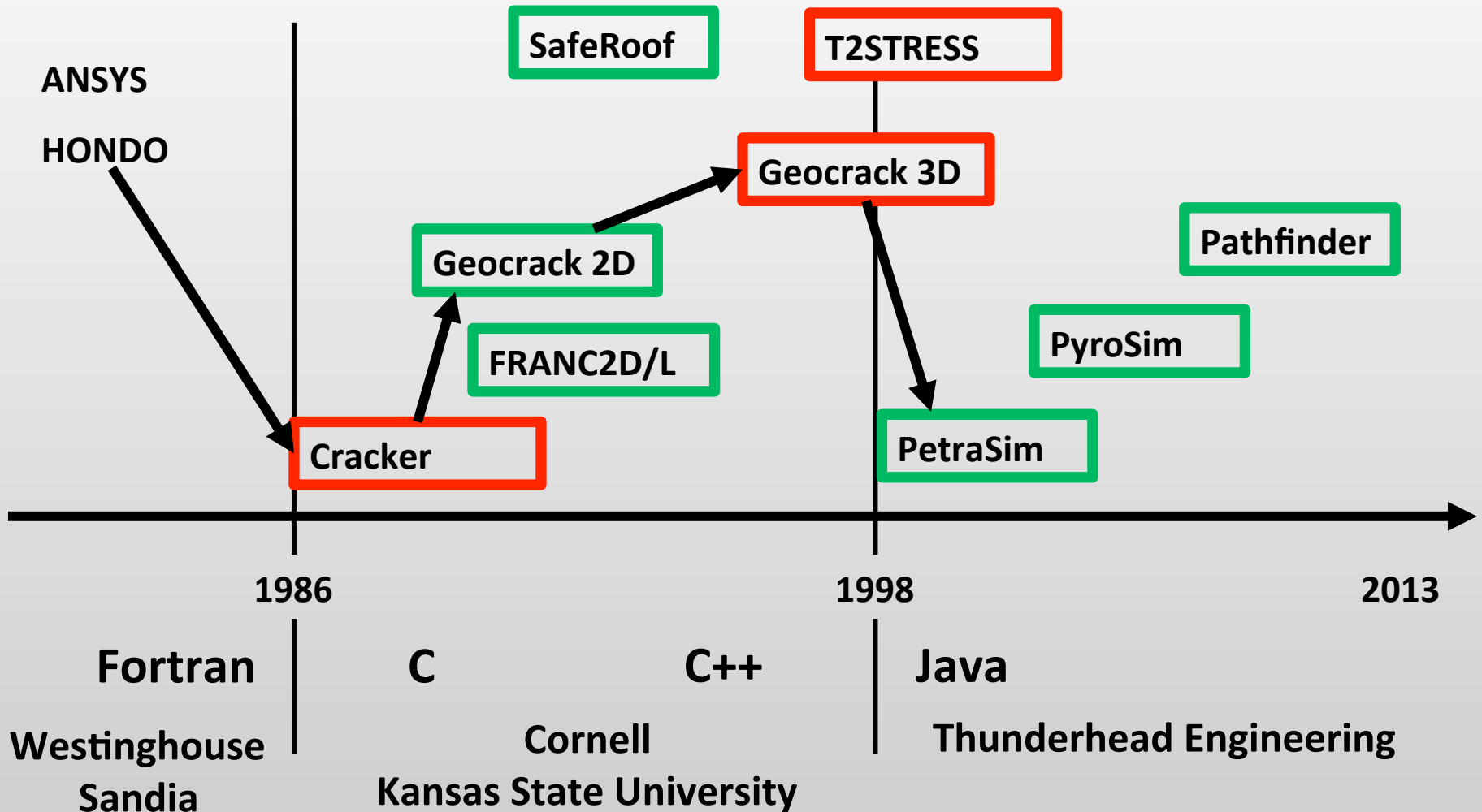


Ethos

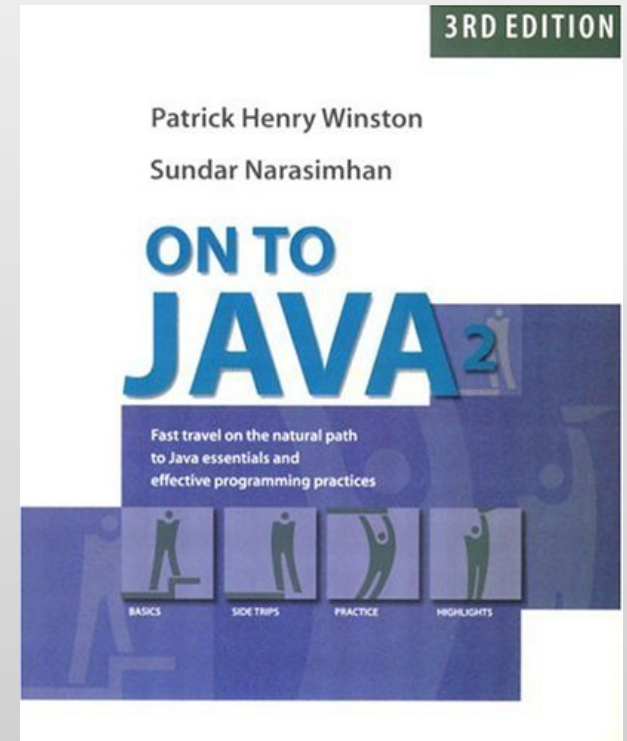
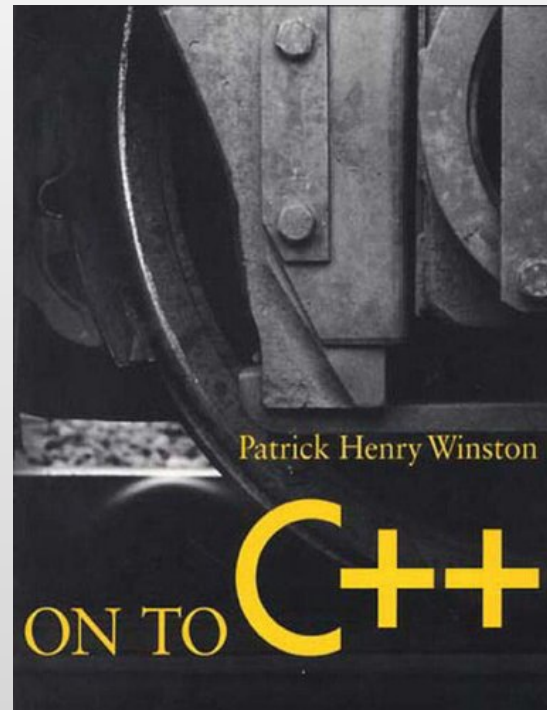
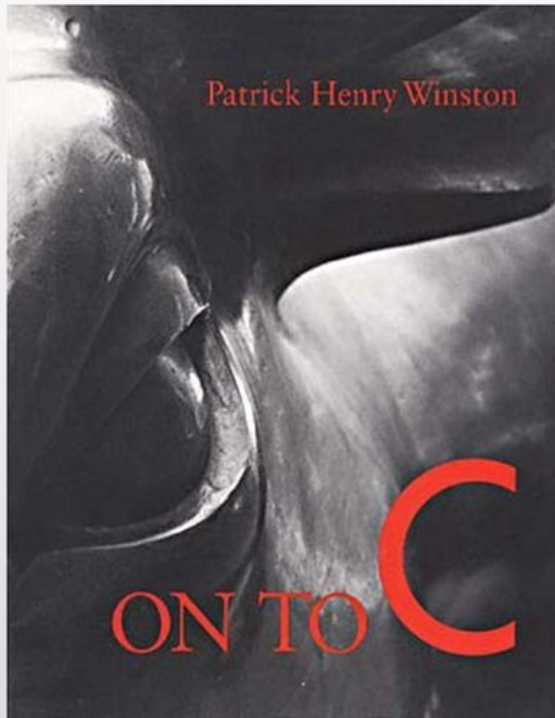


The distinguishing character, sentiment, moral nature, or guiding beliefs of a person, group, or institution.

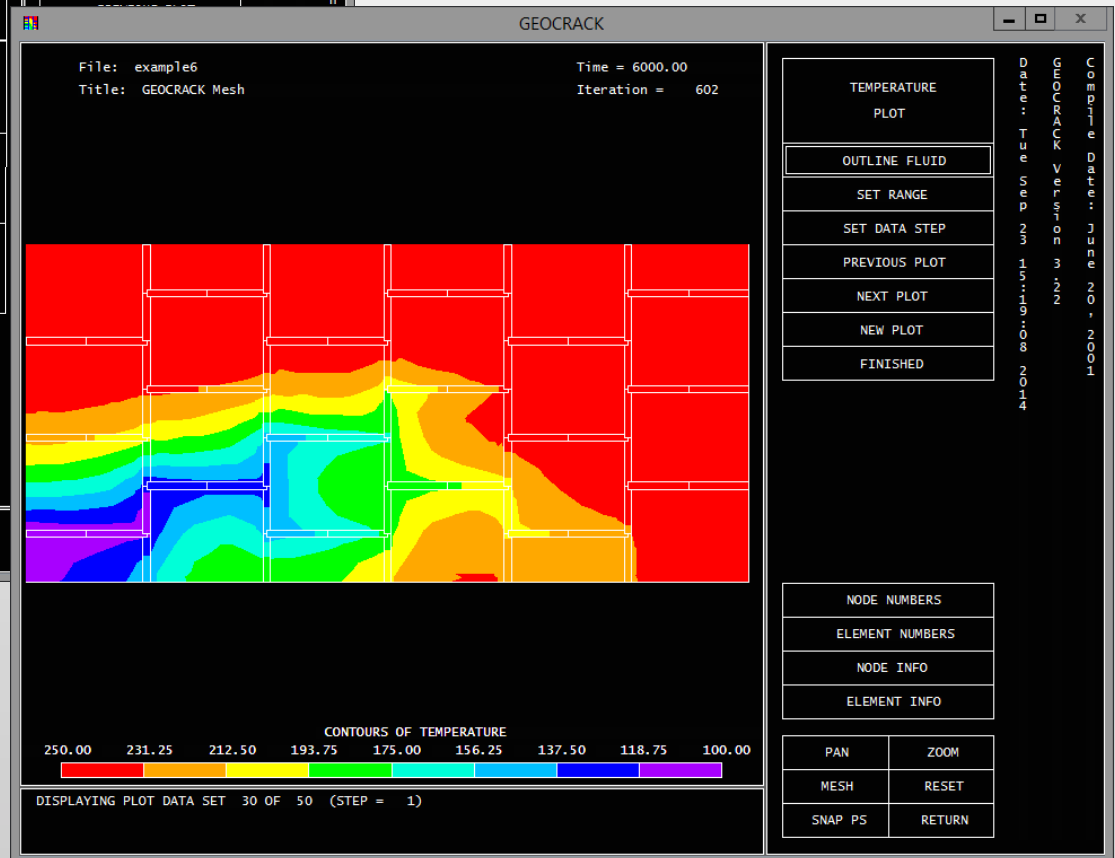
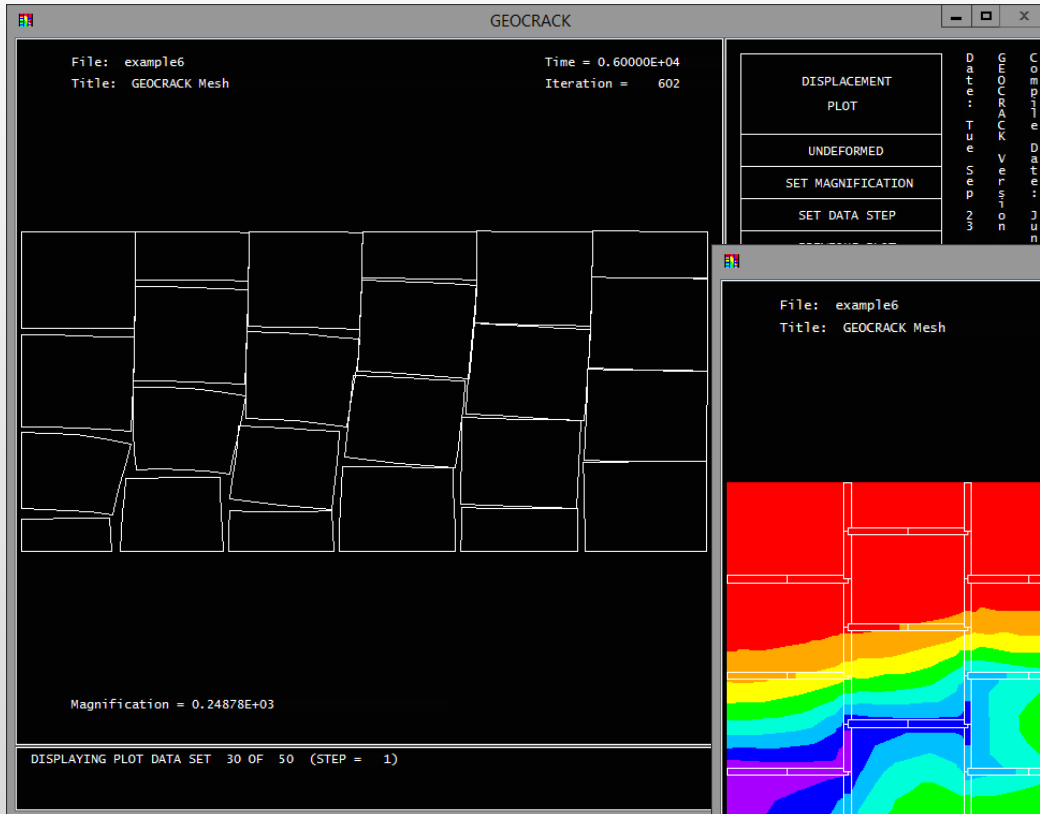
Codes – Living and Dead



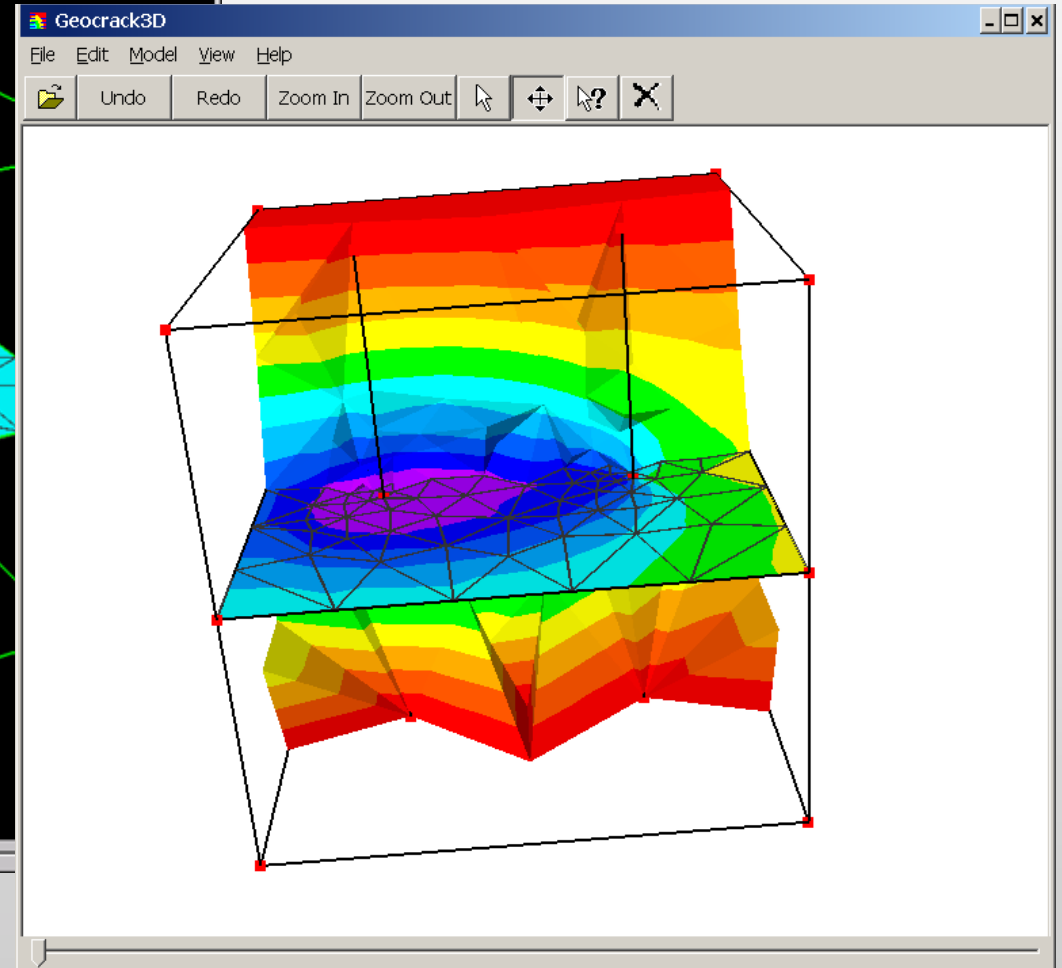
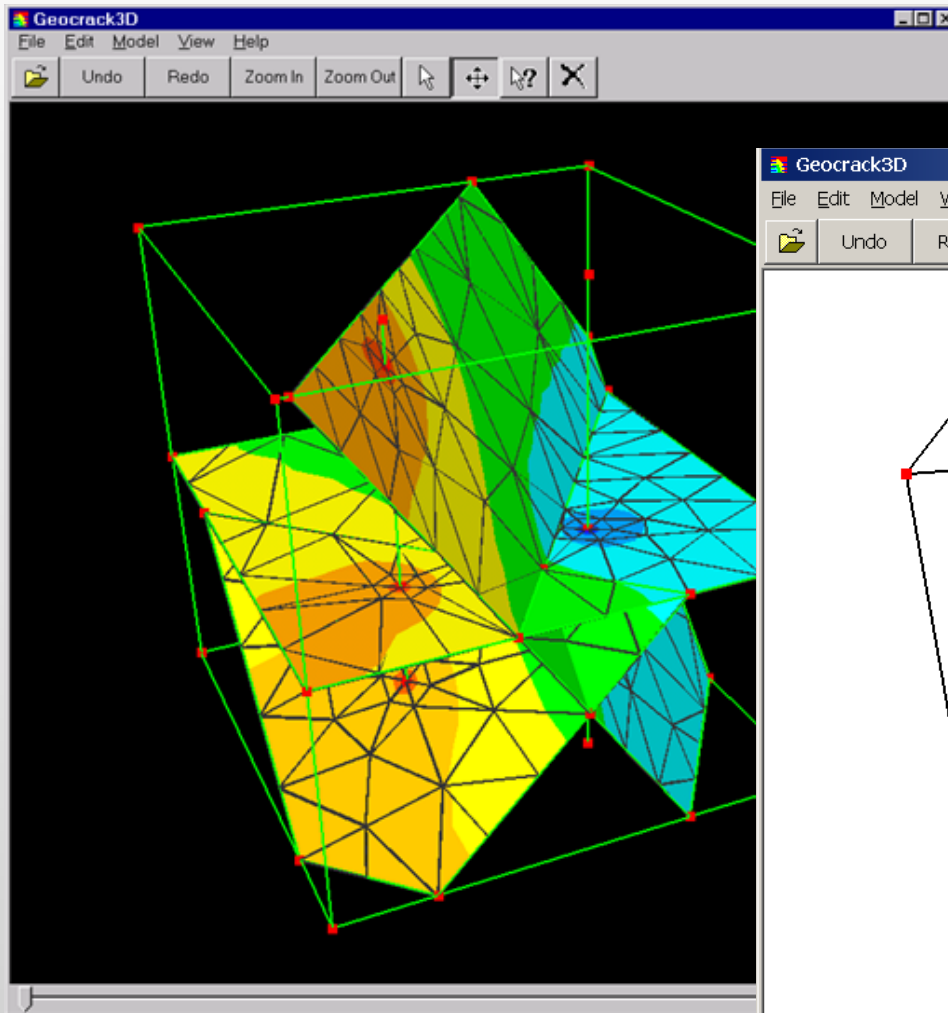
Short Texts



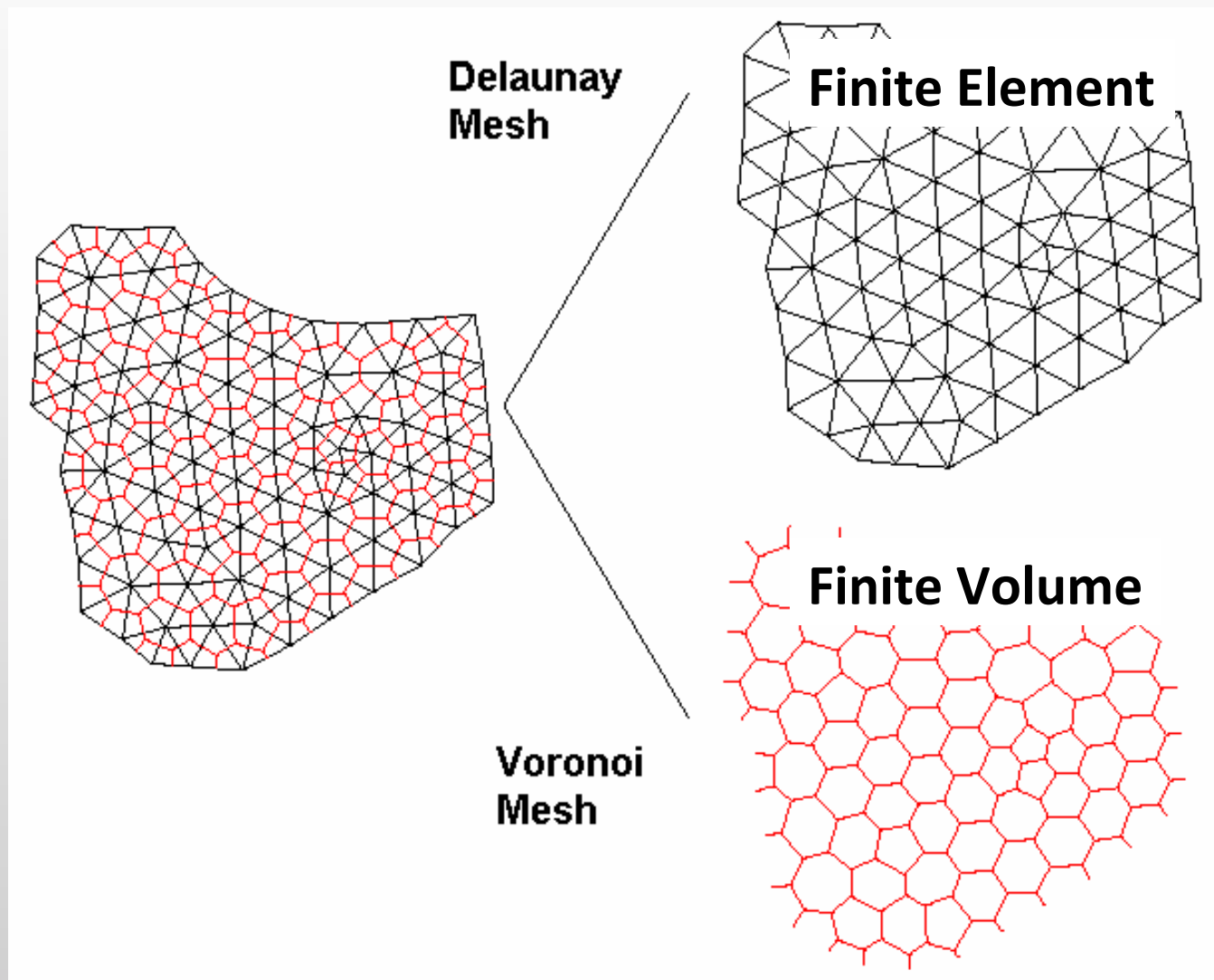
Geocrack 2D



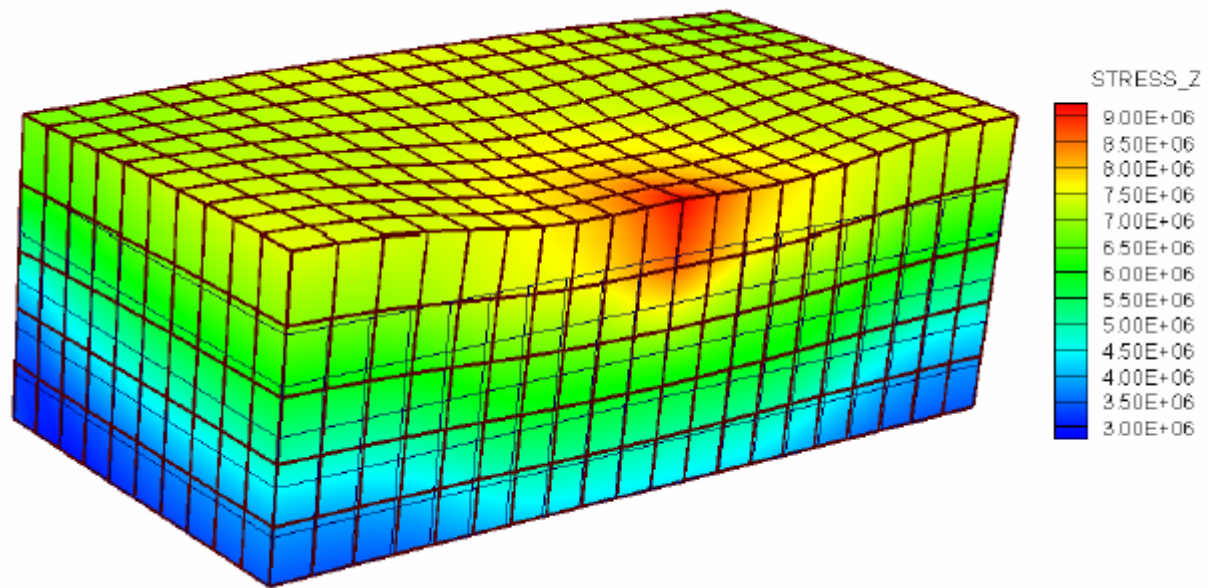
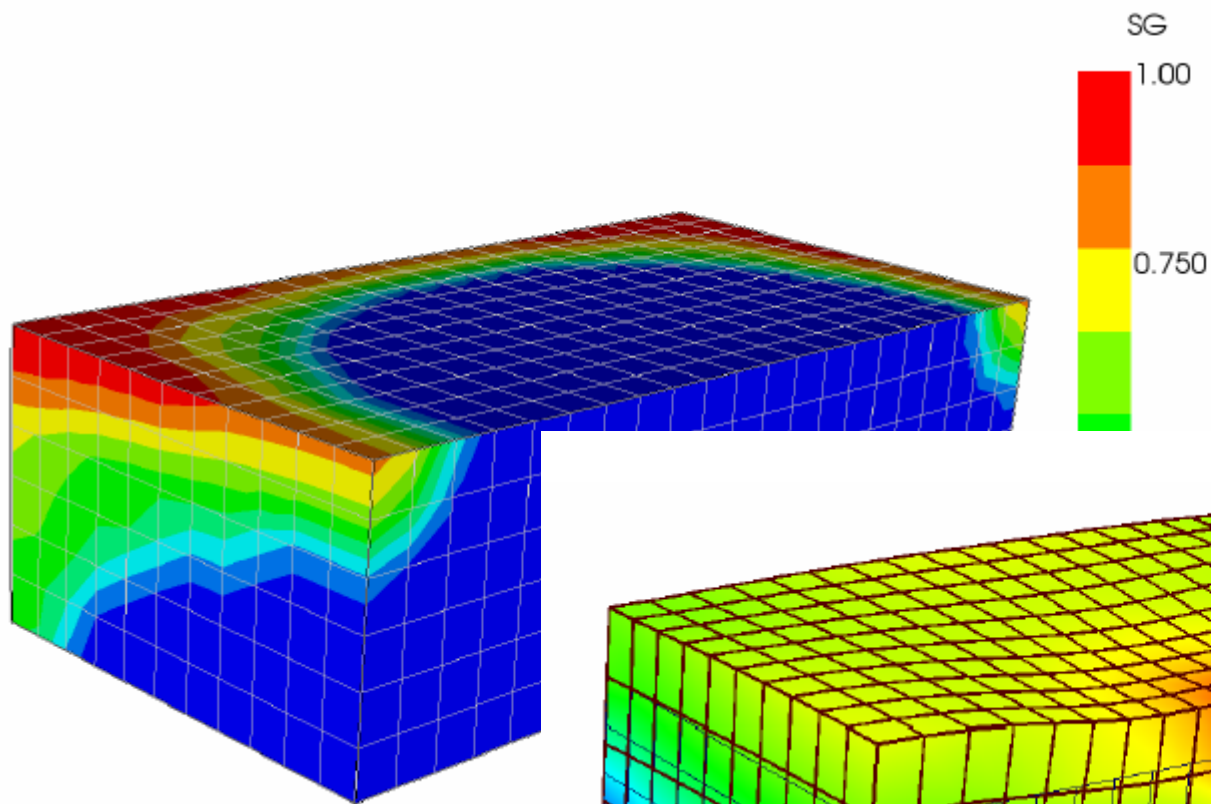
Geocrack 3D



T2STRESS



T2STRESS



Thunderhead Engineering



- 1998
- Brian Hardeman
- Work on Geocrack 2D and 3D gave credibility in geothermal community
- SBIR to develop PetraSim funded by DOE
- Two more SBIR grants – PyroSim and Pathfinder
- Last external funding in 2006

Staff



Remote Staff



HipChat



HipChat

Global Discussion

Thunderhead Engin x

Brian Hardeman x

Status Updates x

Charlie Thornton x

BBD x

Richard O'Konski x

Bryan Klein x

Brandon Lambrecht x

Jon Albrecht x

People

- Brian H
- Bryan K
- Charlie
- Daniel S
- Jon Albr
- Richard

Does that cover it?

Brian Hardem... Basically. They also have interest in new products -- it would be good to think about how we could manage to put effort into new projects and how R&D spending and potential profits would be handled. Sep-22 4:31 PM

Brian Hardem... For example, if they have an idea for Product X, and are willing to help fund its development, how is the development cost shared, and how are revenues from Product X split? Are we even willing to add the capacity to take on new products, etc... Sep-22 4:32 PM

Brian Hardem... How can we work with them, improve our products, give them a competitive advantage (their main business is still consulting), and make us both more money?
Or, business plans for gutter cleaning...
That last one is an old Charlie joke. Sep-22 4:34 PM

Richard O'Ko... I believe the modern version involves alpacas.
But I don't think it's a joke anymore. Sep-22 4:35 PM

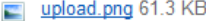
Charlie Thorn... I think we should cut the chatter about alternate business plans unless you want to wait a year to get into them after you move on post aquisition. Sep-22 4:36 PM


September 23, 2014

Calendar Bot (Sep 23, 2014 09:30AM) New Bug Triage Sep-23 9:18 AM

Charlie Thorn... Review for the next version of oculus: <http://www.wired.co.uk/news/archive/2014-09/23/oculus-consumer-vr>
Evidently the pixilation was called "screen door" effect. Sep-23 1:52 PM

Richard O'Ko... I think this will be the kicker for Charlie: "The so-called "screen door" effect, in which the spaces between individual pixels are visible, was completely gone." Sep-23 1:56 PM

Charlie Thorn...  Sep-23 3:06 PM



Richard's theory about the "adding a door makes Pathfinder crash" bug was right on target.
For the record, I don't actually know *why* that is crashing because that kinda should work. But, there it is.

Richard O'Ko... Maybe try "alias" and see if that works. Sep-23 3:07 PM

Charlie Thorn... Yeah, I'm going to try that. Sep-23 3:07 PM

FogBugz



The screenshot shows a web browser window with the URL <https://mhk.thunderheadeng.net/FogBUGZ/default.asp?pgx=LF&ixFilter=43>. The page title is "INBOX - BY PERSON". The interface includes a navigation bar with "List Cases", "New Case", "Send Email", "Filters", "Schedules", and "Wiki". Below the navigation bar, there is a section for "INBOX - BY PERSON" with a filter for "All open cases in Inbox (Not Spam only)" and sorting options: "Assigned To", "Most recently edited cases first", and "Priority".

CASES ASSIGNED TO (THUNDERHEAD STAFF)

<input type="checkbox"/>	Case	Title	Correspondent	Last Updated
<input type="checkbox"/>	27766	Fwd: Fwd: Petrasim License Transfer Sorry about this - the hostid for one of these was missing a dig...	"Alison Alcott" <alison@r...	9/26/2014 (Today)
<input type="checkbox"/>	27662	Status ärende [ITG:00175120], Licens går ut Thanks Bryan, have a nice week-end. :) Med vänlig h...	"IT Gården Drift" <drift@...	9/26/2014 (Today)
<input type="checkbox"/>	27778	request for a new activation key for a new computer Dear Bryan, Attached is the form filled in. Th...	"Ko, Yoon" <Yoon.Ko@nr...	9/26/2014 (Today)
<input type="checkbox"/>	27560	Atkins Renewal / GB-OPP-112420 Hi Bryan, They just want to renew whatever is due to be renewed...	"Salvage, Hannah" <Han...	9/26/2014 (Today)
<input type="checkbox"/>	25544	Ministry of Public works tender (Kuwait) Dear Bryan Finally we signed the contract with MPW. Pleas...	"Jamal R. Dawood" <jam...	9/26/2014 (Today)
<input type="checkbox"/>	27801	(Untitled) Quick question. Trying to extract a room after importing a CAD file and it picks up a lot of...	"Ger Hodson" <gerhodso...	9/26/2014 (Today)
<input type="checkbox"/>	26701	(Untitled) Hi Bryan, a few days ago I approved the Price... Still waiting for the invoice... Saludos, P...	"Pedro Murciego Delgado..."	9/26/2014 (Today)
<input type="checkbox"/>	27788	installion license Hello: Thank you for your reply promptly. I am a graduate from Graduate School ...	"zhaojing" <zhaojing@bj...	9/25/2014 (Yesterd
<input type="checkbox"/>	27799	Academic license request : Gachon University Dear Bryan. I attached a academic license request let...	"베이시스소프트 김민수" <...	9/25/2014 (Yesterd
<input type="checkbox"/>	27636	Pathfinder licence, migrate and some question Hello Bryan, I send you attached my pth file I worke...	"Flamella" <info@flamell...	9/25/2014 (Yesterd
<input type="checkbox"/>	27798	TRIAL LICENCE FILE REQUEST HELLO the licence code shown on the e mail for the pathfinder 64x ...	"jorge enrique gomez ru..."	9/25/2014 (Yesterd
<input type="checkbox"/>	27797	Request for NEW License Key - (was-Fwd: RockWare, Inc.: Cash Sale #19536) Hello Support, Pleas...	"Michael Devine" <mike...	9/25/2014 (Yesterd
<input type="checkbox"/>	24874	PyroSim Training ideas Dear Bryan, I would like to organize some web training in Pyrosim as you a...	"Lascelles Richard" <rick...	9/25/2014 (Yesterd

Source Control



The screenshot shows a source control interface for a project named 'squall_thunderhead'. The left sidebar displays a file tree with folders like 'BehemothApp', 'complang', 'deploy', 'directshow', 'directx', 'fp', 'fpcamserver', 'fpcmd', 'FPCControlRoom', 'FPInstructor', 'fpserver', 'FPTrainer', 'gl', 'icons', 'inferno', 'data2', 'finite', 'geom', 'io', 'parse2', 'sim', 'test', 'util', 'vis', and files like 'SPTTest.java #0/3 <text>' and 'TestSim.java #0/15 <text>'. The main area shows a revision history table with columns for Revision, Date Submitted, Submitted By, and Description. Revision 24117 is selected. Below the table is a 'Details' section with a table of files and their revisions.

Revision (Change)	Date Submitted	Submitted By	Description
24342	1/6/2014 1:43:47...	okonski	[Pathfinder:inferno] Fixed a crash that could occur if a security camera is initializ...
24198	12/16/2013 1:39:...	thornton	[Pathfinder] changed a variable name to improve clarity
24197	12/16/2013 1:38:...	thornton	[Pathfinder] added a method to WingedEdge that can be used to verify that tl a...
24181	12/13/2013 4:00:...	thornton	[Pathfinder] removed and unused import
24166	12/12/2013 2:13:...	okonski	[Pathfinder FP] Added the ability for the decals from appearance mods come an...
24158	12/11/2013 10:4:...	thornton	[Pathfinder] fixed a bug in our TestSim runner that caused all PTH files to run in ...
24152	12/10/2013 8:59:...	okonski	[Pathfinder FP] Updated the teci libs and began work on damage regions/textur...
24117	12/4/2013 3:14:1...	thornton	[Pathfinder] removed the dual geommesh / navmesh in favor of just the mesh. ...
24115	12/4/2013 2:52:3...	thornton	[Pathfinde FP] added a -sphere selector to the STATUS api command for agents ...
24112	12/4/2013 10:27:...	okonski	[Pathfinder:inferno] Added a couple methods to find triangles and edges.
24072	11/27/2013 5:00:...	okonski	[Pathfinder FP] Added the API to remotely control security cameras and made it...
24048	11/25/2013 2:43:...	okonski	[Pathfinder] Made security cameras (formerly "controlled" cameras) have a maxi...
24010	11/19/2013 4:02:...	okonski	[Pathfinder FP] Began work on viewing cameras in Behemoth and FP Instructor. ...
23976	11/14/2013 2:13:...	okonski	[Pathfinder] Updated the teci libs.
23898	11/7/2013 4:12:2...	thornton	[Pathfinder] Added "severe" injuries to FP. Right now they are pretty similar to "a...
23897	11/7/2013 4:10:4...	thornton	[Pathfinder] removed an unused variable
23802	10/23/2013 4:49:...	thornton	[Pathfinder FP] Added API command IDLE {on off}. Idle occupants always think ...
23775	10/17/2013 11:5:...	thornton	[Pathfinder FP] changed the add_agent command in the following ways: -door ...
23660	10/2/2013 4:35:1...	okonski	[Pathfinder:inferno] Fixed BugId: 23232 - Occupants don't use door right next to ...
23622	9/30/2013 10:25:...	thornton	[Pathfinder] in the summary file node names are now left justified, flow rates no...
23503	9/10/2013 10:40:...	okonski	[Pathfinder:inferno] Fixed BugId: 22892 - Improve acceleration.

Name	Revision	Action	Filetype	In Folder
DoorTarget.j...	8	edit	text	//depot/Pathfinder/src/inferno/sim/steering/locallyquic...
Elevator.java	8	edit	text	//depot/Pathfinder/src/inferno/data2
Engine.java	47	edit	text	//depot/Pathfinder/src/inferno/sim
EngineOp.ja...	17	edit	text	//depot/Pathfinder/src/inferno/sim
Estimate.java	22	edit	text	//depot/Pathfinder/src/inferno/sim/path
ExitGoal.java	10	edit	text	//depot/Pathfinder/src/inferno/data2/ai
GLView.java	8	edit	text	//depot/Pathfinder/src/inferno/vis
InfernoUtil.j...	54	edit	text	//depot/Pathfinder/src/merlin/actions
KB.java	42	edit	text	//depot/Pathfinder/src/inferno/sim

Error Handling



Pathfinder Error

Pathfinder has encountered an unknown error and must shut down.

Log File: [pathfinder_crash1409695118688.log](#)

What were you doing at the time of the crash?

Include action history

Please enter your email address to help us fix this bug.

Reply address:

To see what data this error report contains, [click here.](#)

Error Report

```
9:57:30 PM: Merlin3DSelector.selectSingle
9:57:29 PM: Merlin3DSelector.selectSingle
9:57:18 PM: Merlin3DSelector.selectSingle
9:57:12 PM: Merlin3DSelector.selectSingle
9:57:09 PM: Merlin3DSelector.selectSingle

Pathfinder Version: 2014.2.0818 x64
Date: Sep 2, 2014 10:11:11 PM

Stack Trace:
java.lang.RuntimeException
    at merlin.MerlinApp$AWTCrashAction.actionPerformed(Unknown Source)
    at javax.swing.SwingUtilities.notifyAction(Unknown Source)
    at javax.swing.JComponent.processKeyBinding(Unknown Source)
    at javax.swing.JComponent.processKeyBindings(Unknown Source)
    at javax.swing.SwingUtilities.processKeyBindings(Unknown Source)
    at javax.swing.UIManager$2.postProcessKeyEvent(Unknown Source)
    at java.awt.DefaultKeyboardFocusManager.dispatchEvent(Unknown Source)
    at java.awt.DefaultKeyboardFocusManager.preDispatchKeyEvent(Unknown Sour
    at java.awt.DefaultKeyboardFocusManager.typeAheadAssertions(Unknown Sour
    at java.awt.DefaultKeyboardFocusManager.dispatchEvent(Unknown Source)
    at java.awt.Component.dispatchEventImpl(Unknown Source)
```

Quality Assurance Process



- Source Code Control
- Continuous Integration
 - Entire system rebuilt after every change
- Automated Testing
 - Tests run automatically after every build
 - 117 test cases in 2012
 - 308 test cases in 2014
- Testing Dashboard
- Automated Error Reporting
 - Reports categorized and scheduled weekly



Revision Graph - //depot/Pathfinder/src/Inferno/sim/Engine.java (halo:1666, hardeman)

File Filter Tree

- depot
 - inferno
 - merlin
 - Pathfinder
 - src/Inferno/sim
 - Engine.java
 - pathfinder-2011
 - pathfinder-2012
 - pathfinder-2013
 - pathfinder-2014

Revision Graph

65 22978 23032 23034 23622 24064 24072 24117 24469 24497 24501 24512 24913 25306

//depot/Inferno/Inferno/sim/Engine.java

1

//depot/pathfinder-2011/src/Inferno/sim/Engine.java

//depot/merlin/src/Inferno/sim/Engine.java

41 42 43 44 45 46 47 48 49 50

//depot/Pathfinder/src/Inferno/sim/Engine.java

1 2 3

//depot/pathfinder-2013/src/Inferno/sim/Engine.java

1 2

//depot/pathfinder-2014/src/Inferno/sim/Engine.java

2

//depot/pathfinder-2012/src/Inferno/sim/Engine.java

Details Integrations Labels Preview

Revision: //depot/Pathfinder/src/Inferno/sim/Engine.java#47

Date submitted: 12/4/2013 3:14:11 PM Changelist: 24117

Submitted by: thornton Performer filetype: text

Workspace: AUTUMN_thornton File size: 47.7 KB

Action: edit

Description: [Pathfinder] removed the dual geommesh / navmesh in favor of just the mesh. For a confusing. Code archeologists may be interested in knowing that the navmesh is the

Engine.java#46 and Engine.java#47 - Performer P4Merge

2 diffs (Ignore line ending differences) | Tab spacing: 4 | Encoding: System

```
public boolean isStuck(Engine engine)
{
    update(engine);
    return d_stuck;
}

private void updateVis()
{
    d_ticks.begin("RENDERER");
    if (d_param.show_vis)
    {
        final List allRender = new ArrayList();
        allRender.addAll(Arrays.asList(d_Kb.getGeomMesh().getVerts()));
        allRender.addAll(Arrays.asList(d_Kb.getGeomMesh().getEdges()));
        allRender.addAll(Arrays.asList(d_Kb.getGeomMesh().getTris()));

        allRender.addAll(d_occAgents);
        for (ANode node : d_Kb.getNodes())
        {
            IDensityField df = node.getDensityField();
            allRender.add(df);
        }

        try
        {
            if (!EventQueue.isDispatchThread())
            {
                EventQueue.invokeAndWait(new Runnable()
                {
                    public void run()
                    {
                        synchronized (Engine.this)
                        {
                            if (d_gLView != null) { d_gLView.render(allRender);
                            }
                        }
                    }
                });
            }
        }
        else
        {
            public boolean isStuck(Engine engine)
            {
                update(engine);
                return d_stuck;
            }

            private void updateVis()
            {
                d_ticks.begin("RENDERER");
                if (d_param.show_vis)
                {
                    final List allRender = new ArrayList();
                    allRender.addAll(Arrays.asList(d_Kb.getMesh().getVerts()));
                    allRender.addAll(Arrays.asList(d_Kb.getMesh().getEdges()));
                    allRender.addAll(Arrays.asList(d_Kb.getMesh().getTris()));

                    allRender.addAll(d_occAgents);
                    for (ANode node : d_Kb.getNodes())
                    {
                        IDensityField df = node.getDensityField();
                        allRender.add(df);
                    }

                    try
                    {
                        if (!EventQueue.isDispatchThread())
                        {
                            EventQueue.invokeAndWait(new Runnable()
                            {
                                public void run()
                                {
                                    synchronized (Engine.this)
                                    {
                                        if (d_gLView != null) { d_gLView.render(allRender);
                                        }
                                    }
                                }
                            });
                        }
                    }
                    else
                    {
```

Automated Tests - Dashboard



Test Matrix

halo/autotests/dashboard.php

Results For

- 0 - Pathfinder 2012
- 1 - Pathfinder 2014-0528
- 2 - Pathfinder 2014-0801
- 3 - 24 Hours Ago
- 4 - Latest Build

0	1	2	3	4	Model	Error
?	?	■	■	■	stadiums/merging_flow STEERING	Expected t=242.40 err_tol=5.0%; found t=264.28 err=9.0%
?	?	■	■	■	stadiums/problem1 b STEERING-FSMAX	
?	?	■	■	■	stadiums/problem1 c STEERING-FSMAX	
?	?	■	■	■	stadiums/stuck_merge STEERING	
?	?	■	■	■	stadiums/stuck_narrow STEERING	
?	?	■	■	■	stadiums/up3-smaller STEERING-FSMAX	
?	?	■	■	■	stadiums/up3-smaller counterflow STEERING-FSMAX	
?	?	■	■	■	stadiums/HolonArena STEERING	
?	?	■	■	■	stadiums/Holon-Arena STEERING	
?	?	■	■	■	stadiums/ArteVeldeStadionGent-Simplified-g01-e14 STEERING	
?	?	■	■	■	stadiums/problem1 d STEERING-FSMAX	
?	?	■	■	■	stadiums/problem1 d SFPE	
?	?	■	■	■	stadiums/problem2 STEERING-FSMAX	
?	?	■	■	■	stadiums/problem2 SFPE	
?	?	■	■	■	stadiums/up3 STEERING-FSMAX	
?	?	■	■	■	stadiums/optim3-modif-01 STEERING	Max sim time exceeded. Expected t=1007.80 tol=200.0%
?	?	■	■	■	stadiums/Scn 1C fixed STEERING	Expected t=1104.80 err_tol=5.0%; found t=1288.78 err=16.7%
?	?	■	■	■	elevators/disabled doors/disabled doors STEERING	

Verification and Validation Guide



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www.thunderheadeng.com

Verification and Validation

Pathfinder 2014.2
Release 0730 x64

Pathfinder Verification and Validation

6 Comparisons to Experiments

This section presents Pathfinder models designed to reproduce experimental results.

6.1 Seyfried et al.

This validation test compares Pathfinder to a series of small-scale experiments (Seyfried, Passon, et al., Capacity Estimation for Emergency Exits and Bottlenecks 2007). The experiments were conducted in a room constructed with dividers and an adjustable-width corridor. Once occupants had exited the corridor they were clear of the experimental environment. Figure 37 illustrates the experimental setup.

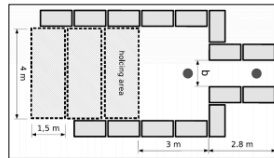


Figure 37: Experimental setup (Seyfried, Passon, et al., Capacity Estimation for Emergency Exits and Bottlenecks 2007).

Each holding area can accommodate 20 occupants, allowing for experiments to be run with 20, 40, and 60 occupants. The corridor width was adjusted in the range from 0.8 m to 1.2 m at 0.1 m intervals. These two variables provide for 15 test cases. Figure 38 shows the Pathfinder model used to simulate all 15 cases. Currently, only the bottom row of test cases can be compared because the experimental data available for direct comparison is limited to the N=60 cases.

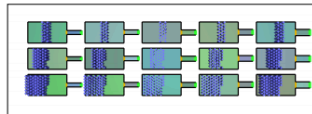


Figure 38: A Pathfinder model designed to replicate all 15 cases of the experiments.

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Pathfinder Verification and Validation

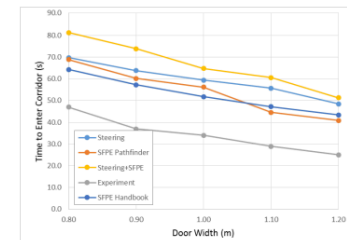


Figure 39: Comparison of times to exit room

In addition, we are able to compare the overhead camera footage in the experiment to the results visualization in Pathfinder. The exact scenario shown in the video at the left of Figure 40 is unknown, but based on the apparent door width and ability of occupants to form two distinct columns, the results video for a steering simulation using door width of 1.1 meters was selected for comparison (at right). The figure was created using the cylinder visualization that illustrates occupant orientation with an inset triangle.

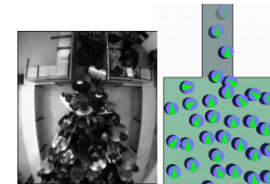
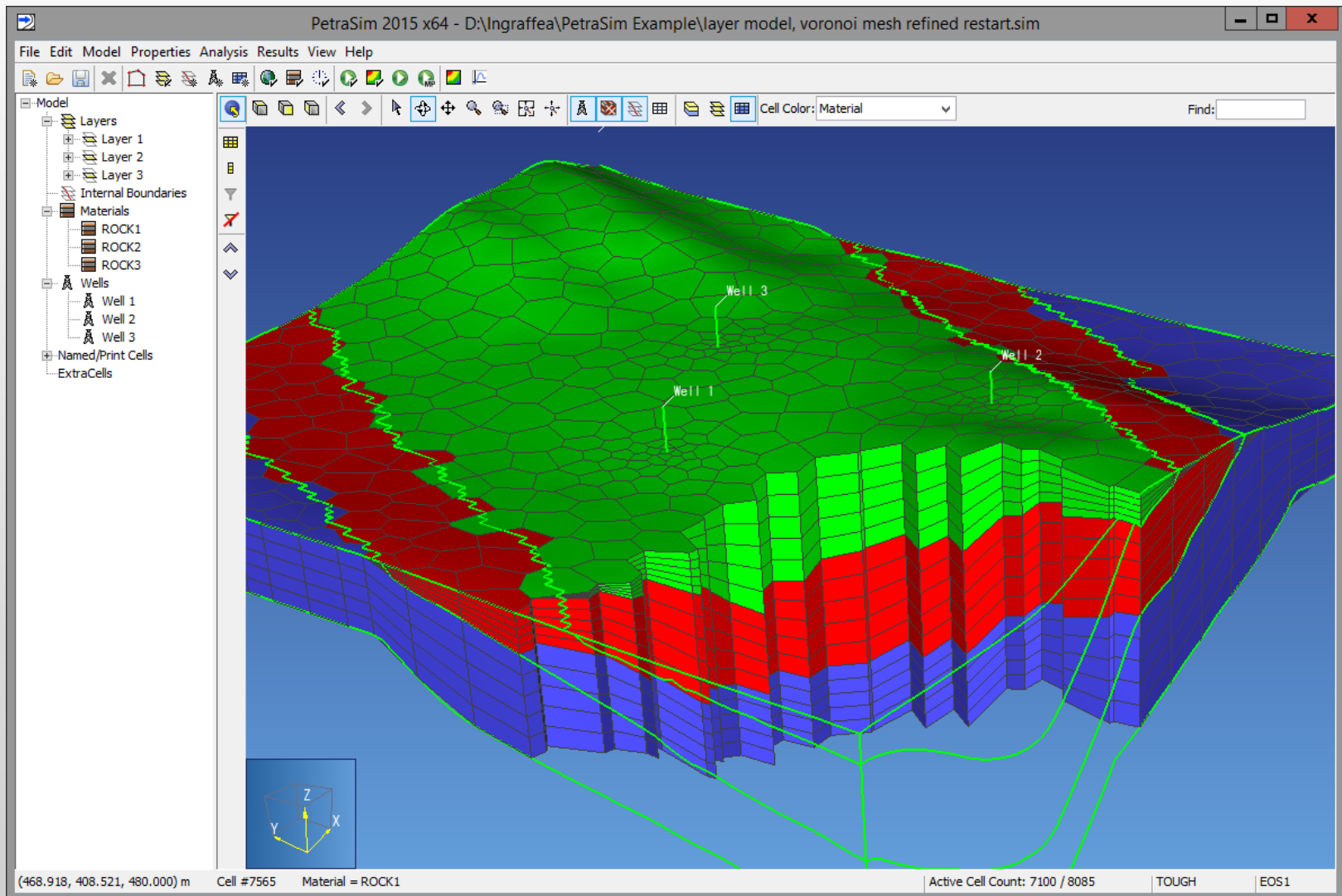


Figure 40: Experimental video (Seyfried, Passon, et al., Pedestrian and Evacuation Dynamics NETWORK 2009) compared to Pathfinder visualization.

48

PetraSim - User Interface to TOUGH2



PetraSim/TOUGH2



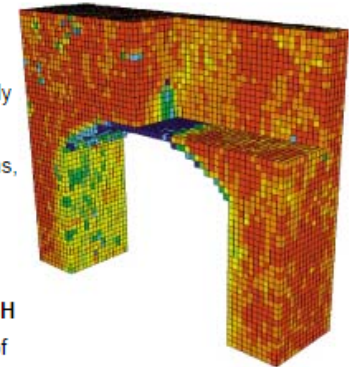
TOUGH

$$\frac{d}{dt} \int_{V_n} M^k dV_n = \int \mathbf{F}^k \cdot \mathbf{n} d\Gamma_n + \int q^k dV_n$$

[Software](#)[Documentation](#)[Licensing & Download](#)[Events](#)[User Support](#)

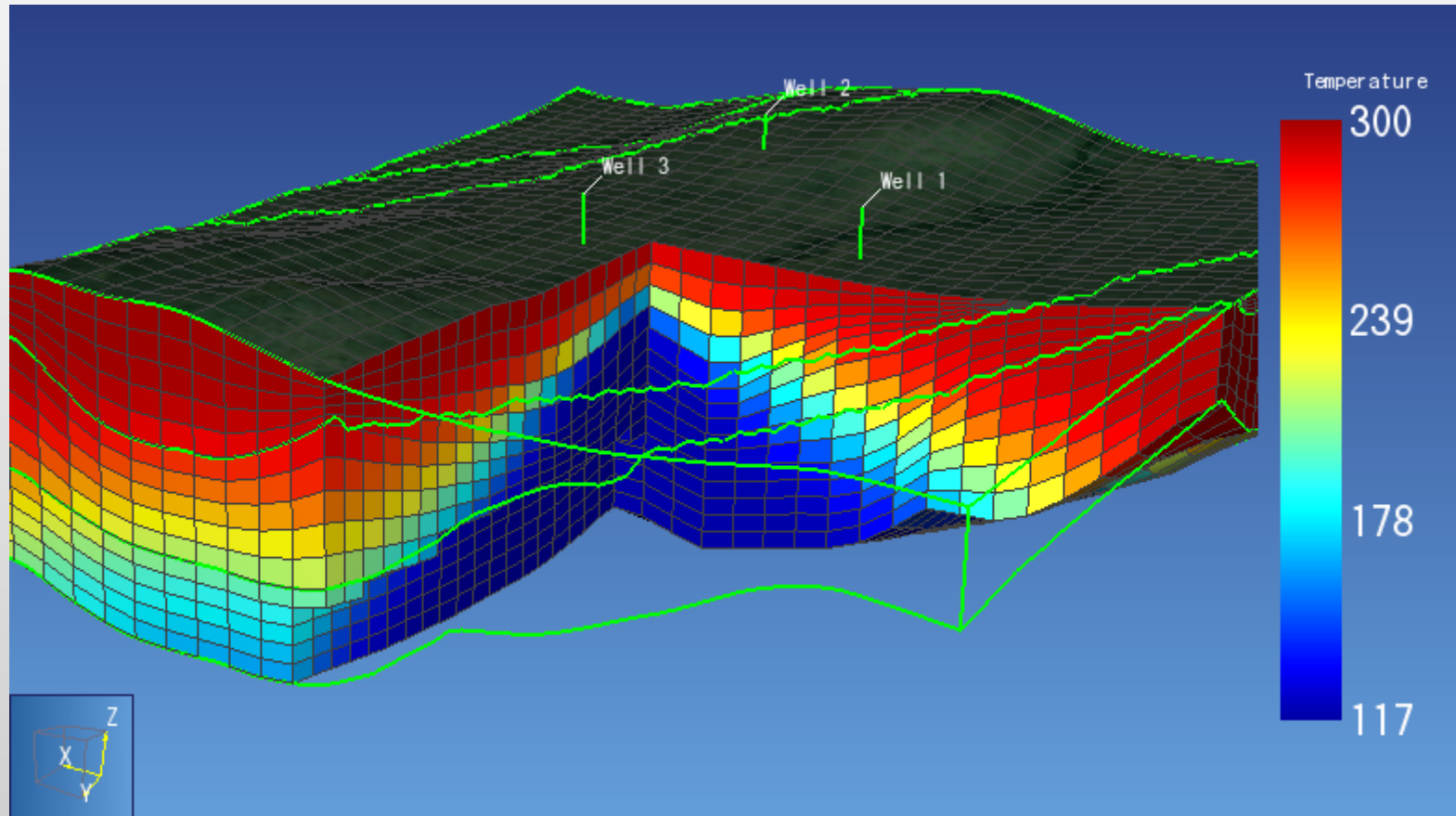
TOUGH: Suite of Simulators for Nonisothermal Multiphase Flow and Transport in Fractured Porous Media

The TOUGH ("Transport Of Unsaturated Groundwater and Heat") suite of software codes are multi-dimensional numerical models for simulating the coupled transport of water, vapor, non-condensable gas, and heat in porous and fractured media. Developed at the Lawrence Berkeley National Laboratory (LBNL) in the early 1980s primarily for geothermal reservoir engineering, the suite of simulators is now widely used at universities, government organizations, and private industry for applications to nuclear waste disposal, environmental remediation problems, energy production from geothermal, oil and gas reservoirs as well as gas hydrate deposits, geological carbon sequestration, vadose zone hydrology, and other uses that involve coupled thermal, hydrological, geochemical, and mechanical processes in permeable media. The TOUGH suite of simulators is continually updated, with new equation-of-state (EOS) modules being developed, and refined process descriptions implemented into the TOUGH framework (see the overview of the TOUGH development [history](#)). Notably, EOS property modules for mixtures of water, NaCl, and CO₂ has been developed and is widely used for the analysis of geologic carbon sequestration processes.

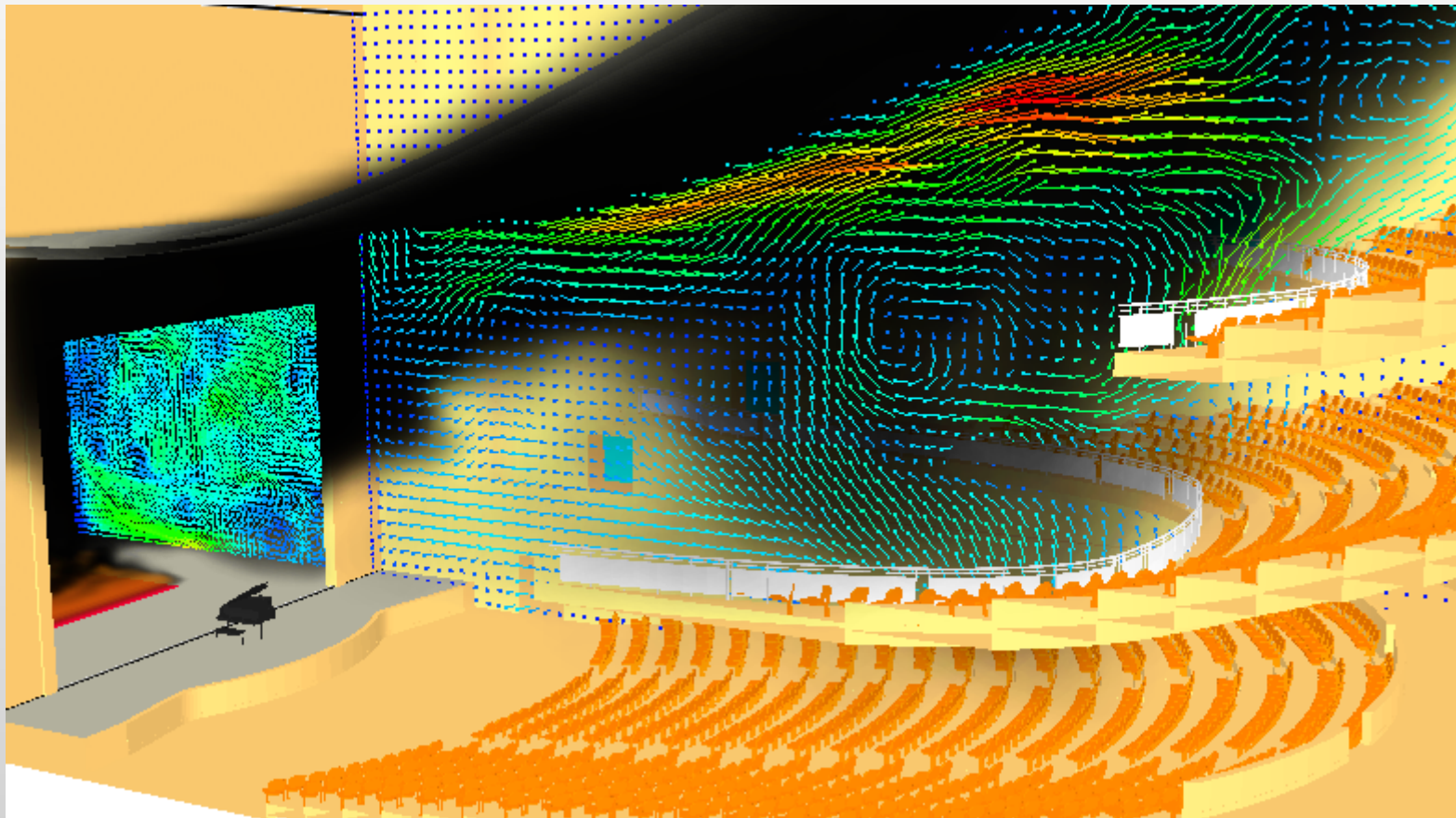


Karsten Pruess was presented a [Lifetime Achievement Award](#) for Development of the TOUGH Codes on Tuesday, September 18th at the 2012 TOUGH Symposium in Berkeley, CA.

PetraSim Results



PyroSim



NIST Fire Dynamics Simulator



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FDS and Smokeview

Description/Summary:

Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires.

Smokeview (SMV) is a visualization program that is used to display the output of FDS and CFAST simulations.

FDS+Evac is the evacuation simulation module for Fire Dynamics Simulator (FDS). The software is used to simulate the movement of people in evacuation situations. The evacuation simulations can be fully coupled with the fire simulations.

More information, including downloads, manuals, and support are available on the [primary FDS and Smokeview website](#).

Details

Type of software: Computational fluid dynamics (CFD) model of fire-driven fluid flow.

System/Platform: FDS and Smokeview are available for the Windows, Linux and Mac OS X platforms.

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Developer Perspective



- Keeping PyroSim up-to-date with FDS
- Parsing FDS input files correctly
- Simplifying input
 - Abstract complex information into simpler ideas
 - Identify common operations and provide shortcut
- Deciding how far to go with geometry creation tools
- Rasterization of geometry

Candle Flame



PyroSim – Modeling Fire Part 1 - Reactions

Reviews how *reactions* are used as the first step in defining fire parameters.

Thanks to Anthony Hamins for providing the FDS candle model. Reference: Anthony Hamins, Matthew Burdy, and Scott Dillon, "Characterization of Candle Flames," Journal of FIRE PROTECTION ENGINEERING, Vol. 27—November 2005, pp. 355-377.

www.thunderheadeng.com

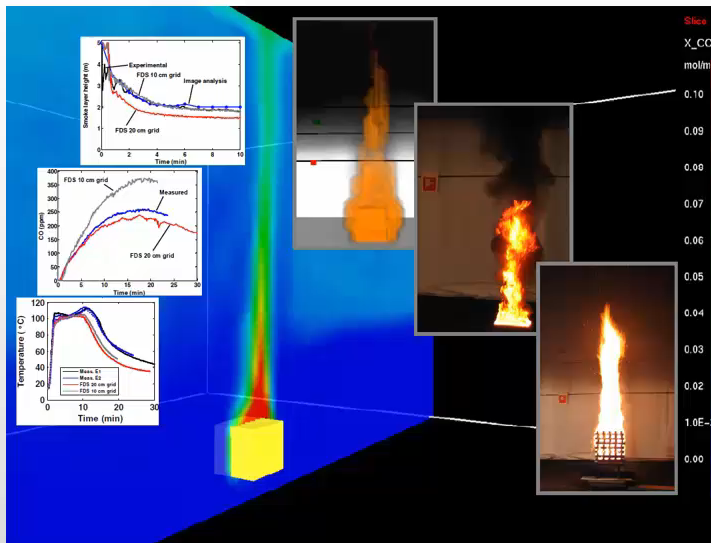
Wood Crib



This Example Based on Research at VTT

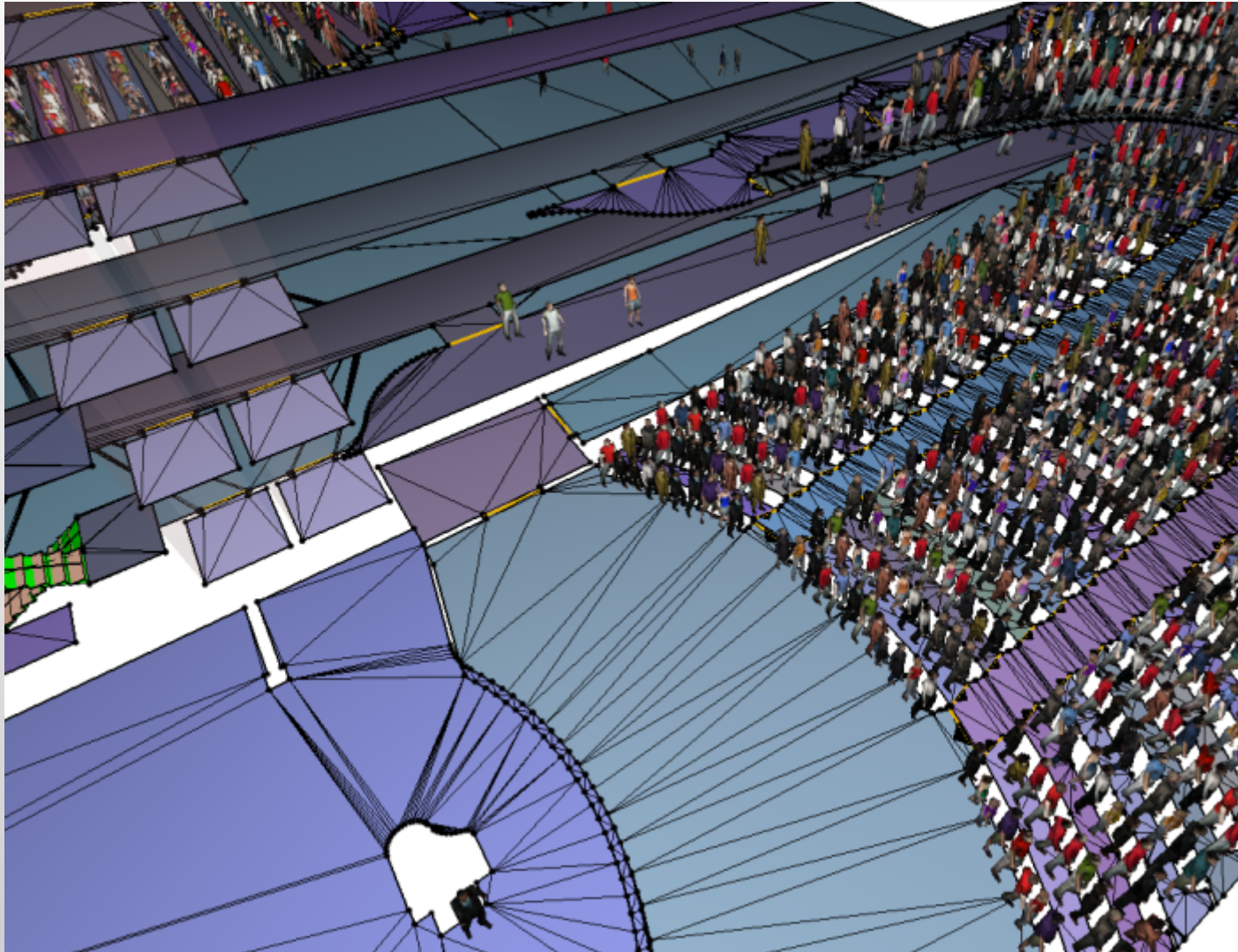
Experimental Validation of the FDS Simulations of Smoke and Toxic Gas Concentrations

Tuomo Rinne, Jukka Hietaniemi & Simo Hostikka
VTT Technical Research Centre of Finland



<http://www.vtt.fi/inf/pdf/workingpapers/2007/W66.pdf>

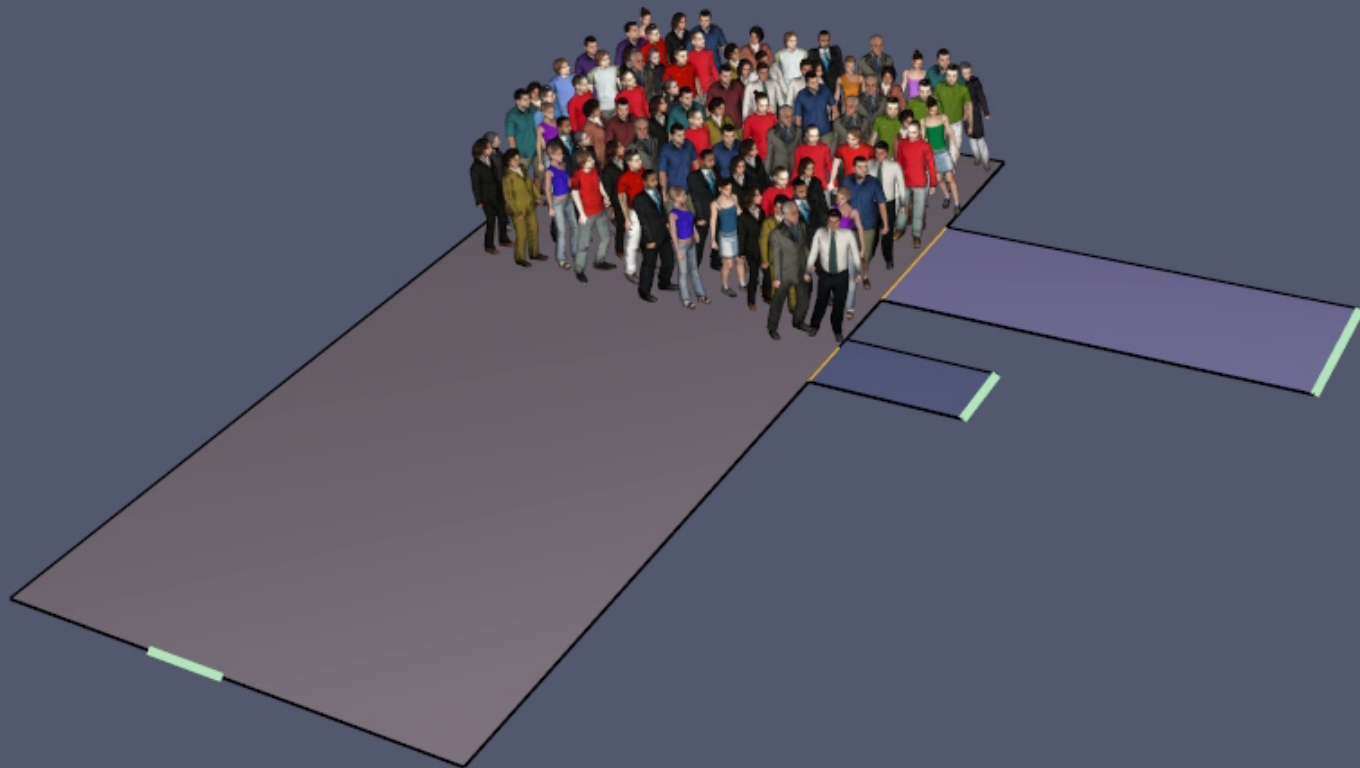
Pathfinder



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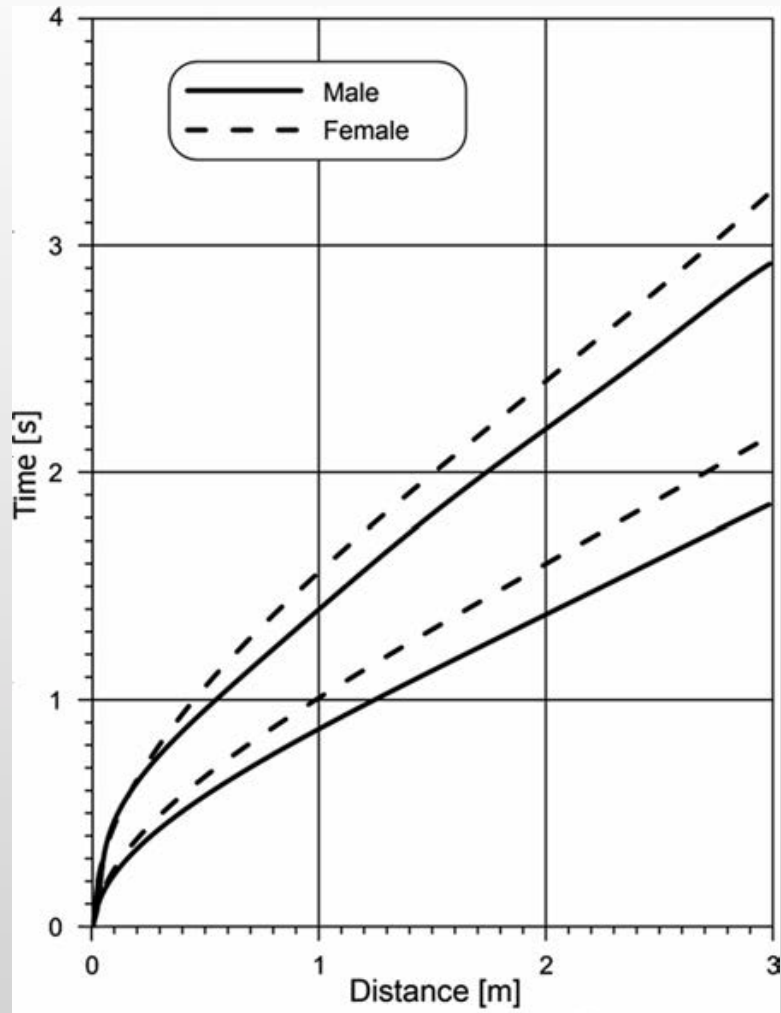
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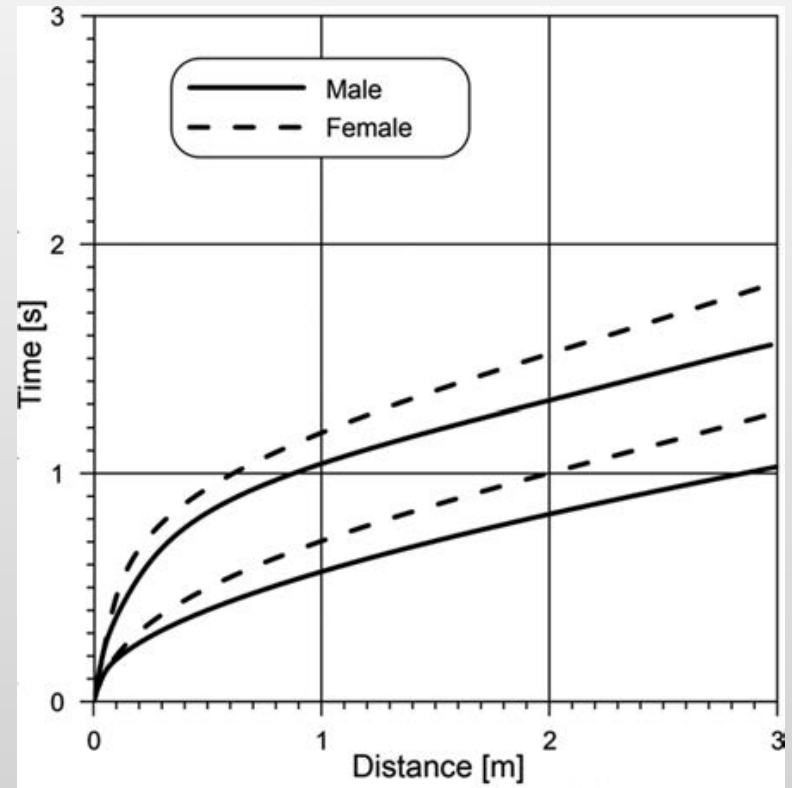
Pedestrian Acceleration



Problems of Forensic Sciences 2012, vol. 91
Jakub Zębala, Piotr Ciępka, Adam Reza
Institute of Forensic Research, Kraków, Poland

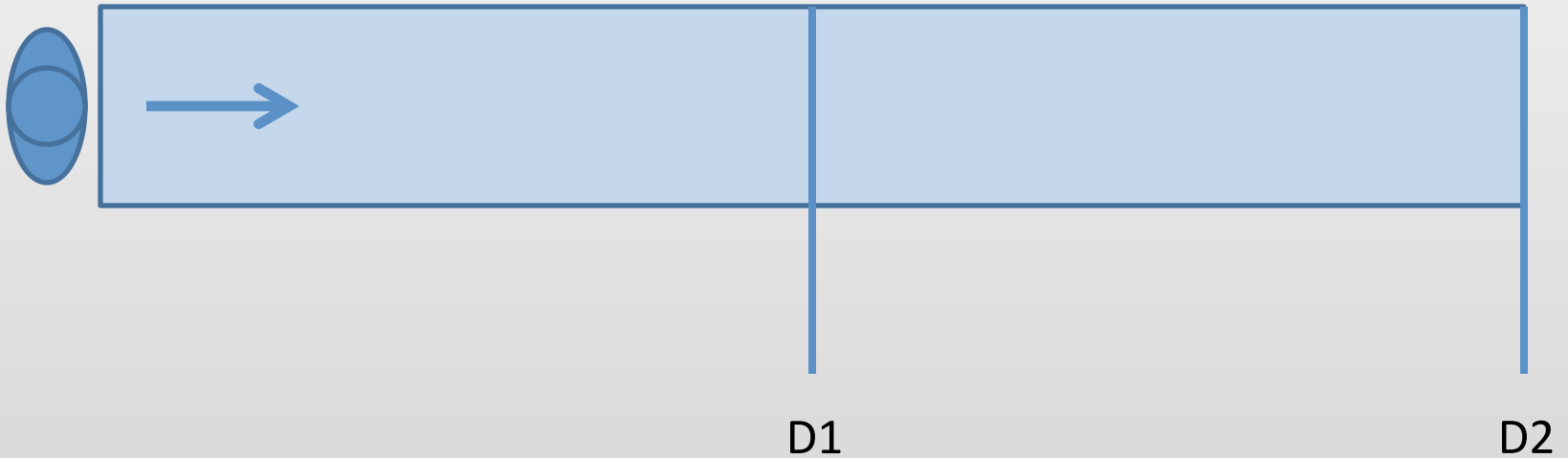


Walking



Sprinting

Hallway Experiment

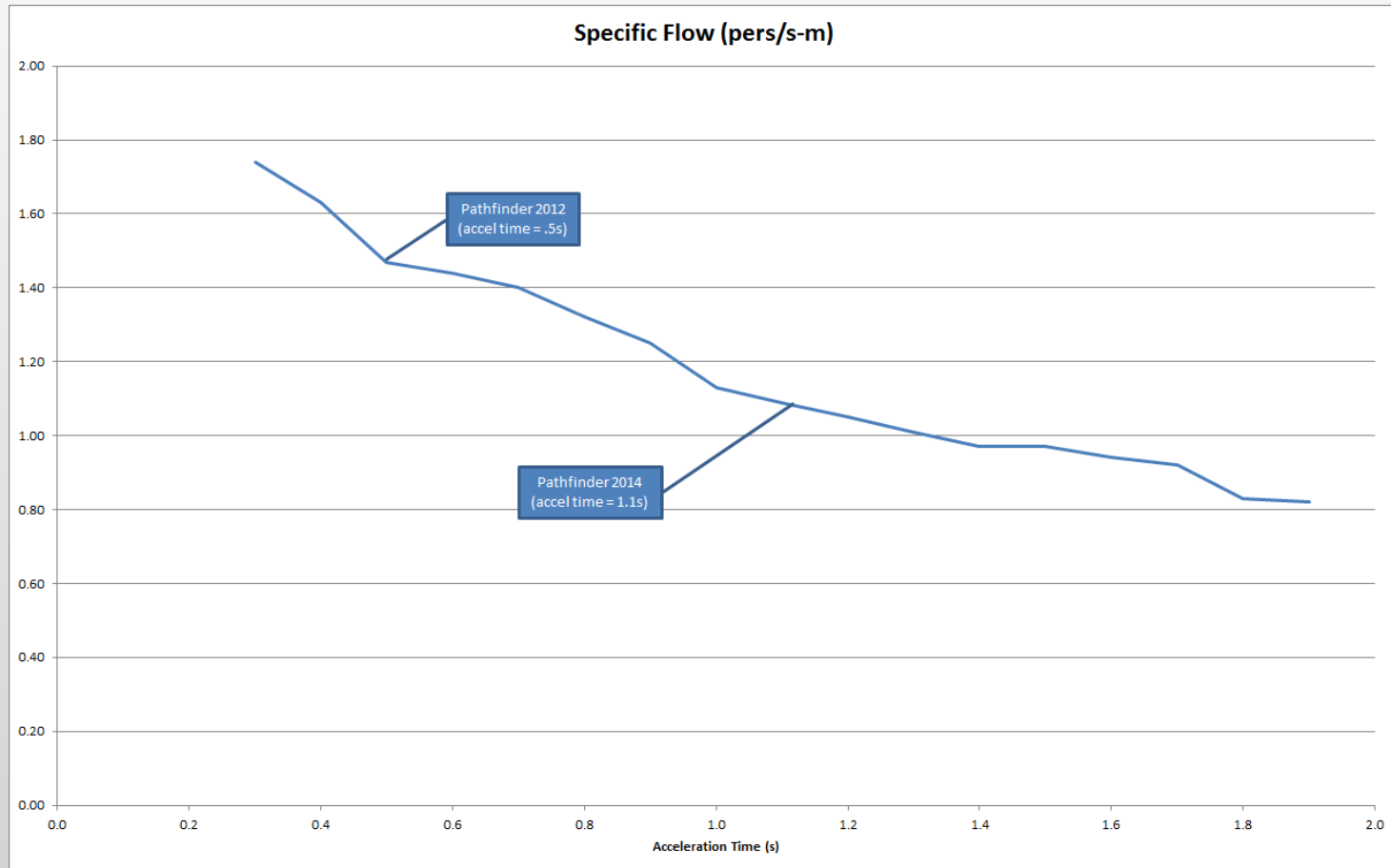


Hallway Results



	D1	D2	t	v	a	a/v	t_accel
Richard1	4.24	3.55	7.79	1.3	0.9	0.7	1.4
Richard2	4.25	3.63	7.88	1.3	1.0	0.8	1.2
Richard3	4.4	3.9	8.3	1.2	1.2	1.0	1.0
Jon1	3.81	3.61	7.42	1.3	3.2	2.5	0.4
Jon2	4.11	3.55	7.66	1.3	1.1	0.9	1.1
Brian1	3.45	3.35	6.8	1.4	6.8	5.0	0.2
Brian2	3.67	3.11	6.78	1.5	1.3	0.9	1.1
Brian3	3.23	3.13	6.36	1.5	7.3	5.0	0.2
Charlie1	4.2	3.74	7.94	1.2	1.3	1.1	0.9
Charlie2	4.38	3.81	8.19	1.2	1.1	0.9	1.1
Joe	3.97	3.7	7.67	1.2	2.3	1.9	0.5
Dan1	3.83	3.25	7.08	1.4	1.2	0.9	1.2
Dan2	3.82	3.07	6.89	1.5	1.0	0.7	1.5
Average					2.3	1.7	0.9

Flow vs. Acceleration



Agent Acceleration

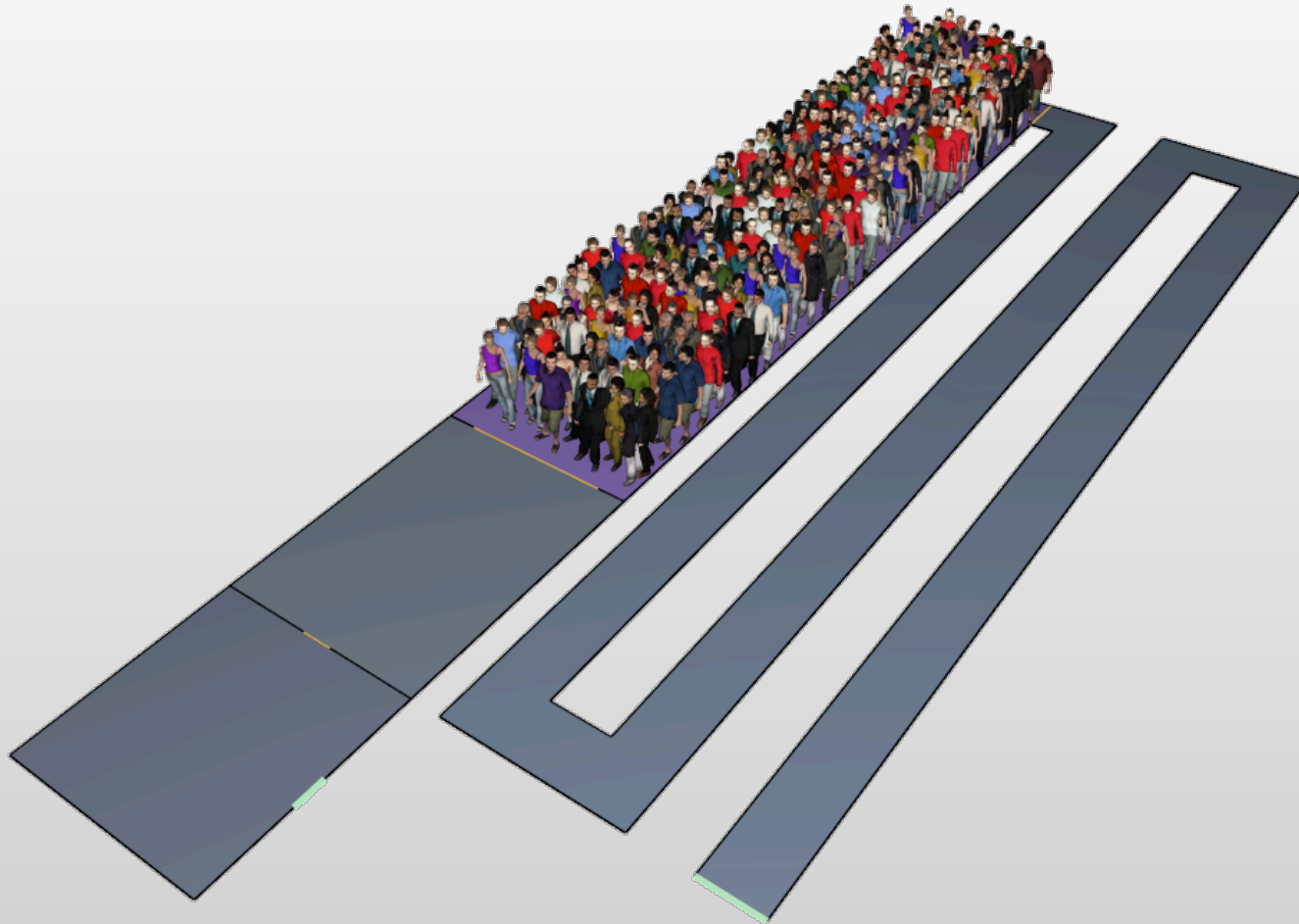


- Changed default value
- Exposed parameter for user input
- Re-run verification problems
- Update tests with new results

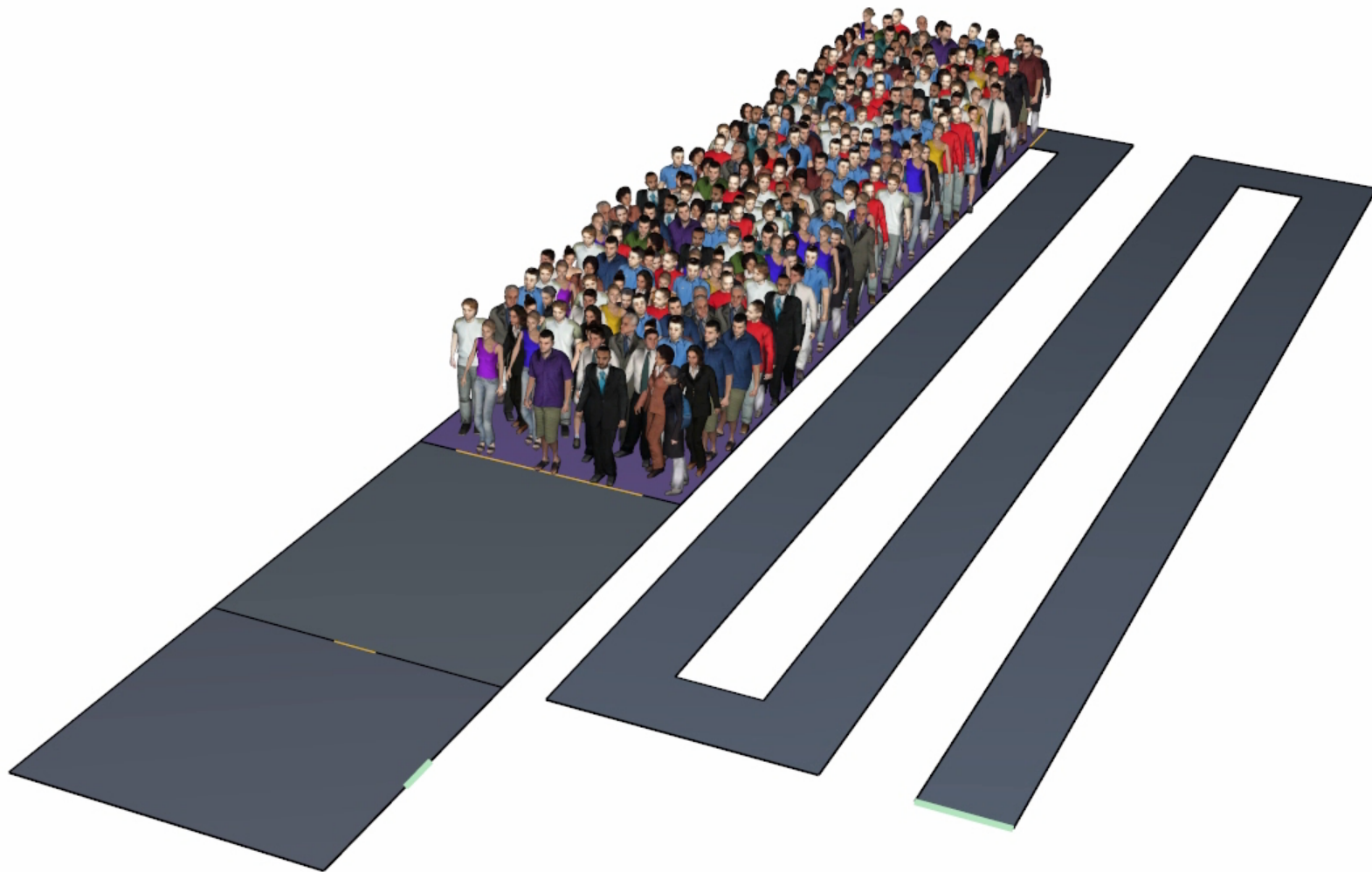
Improving Locally-Quickest Door Choice



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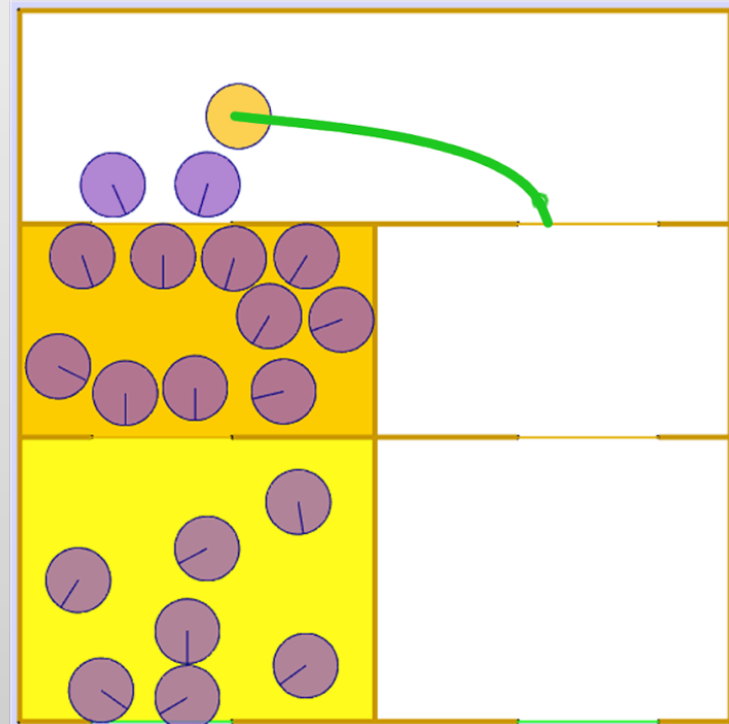
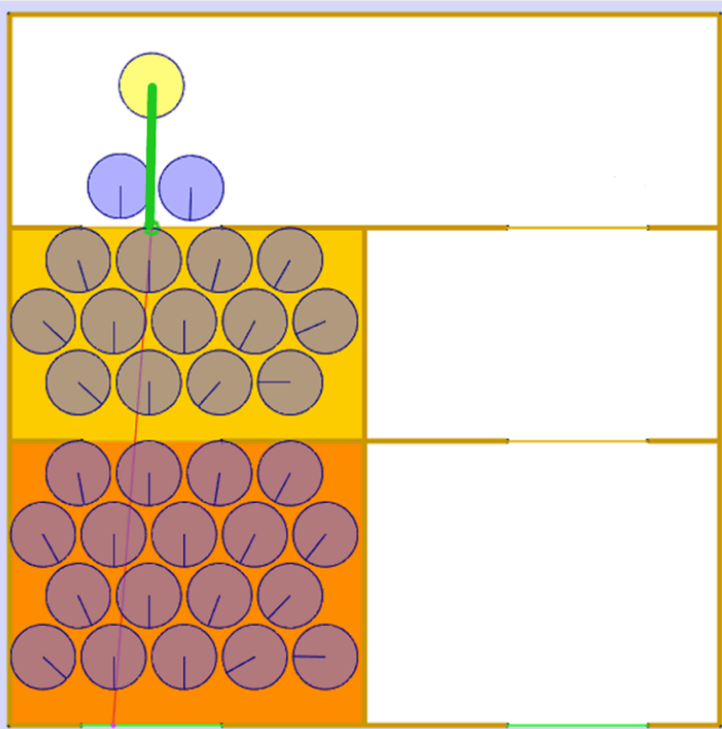
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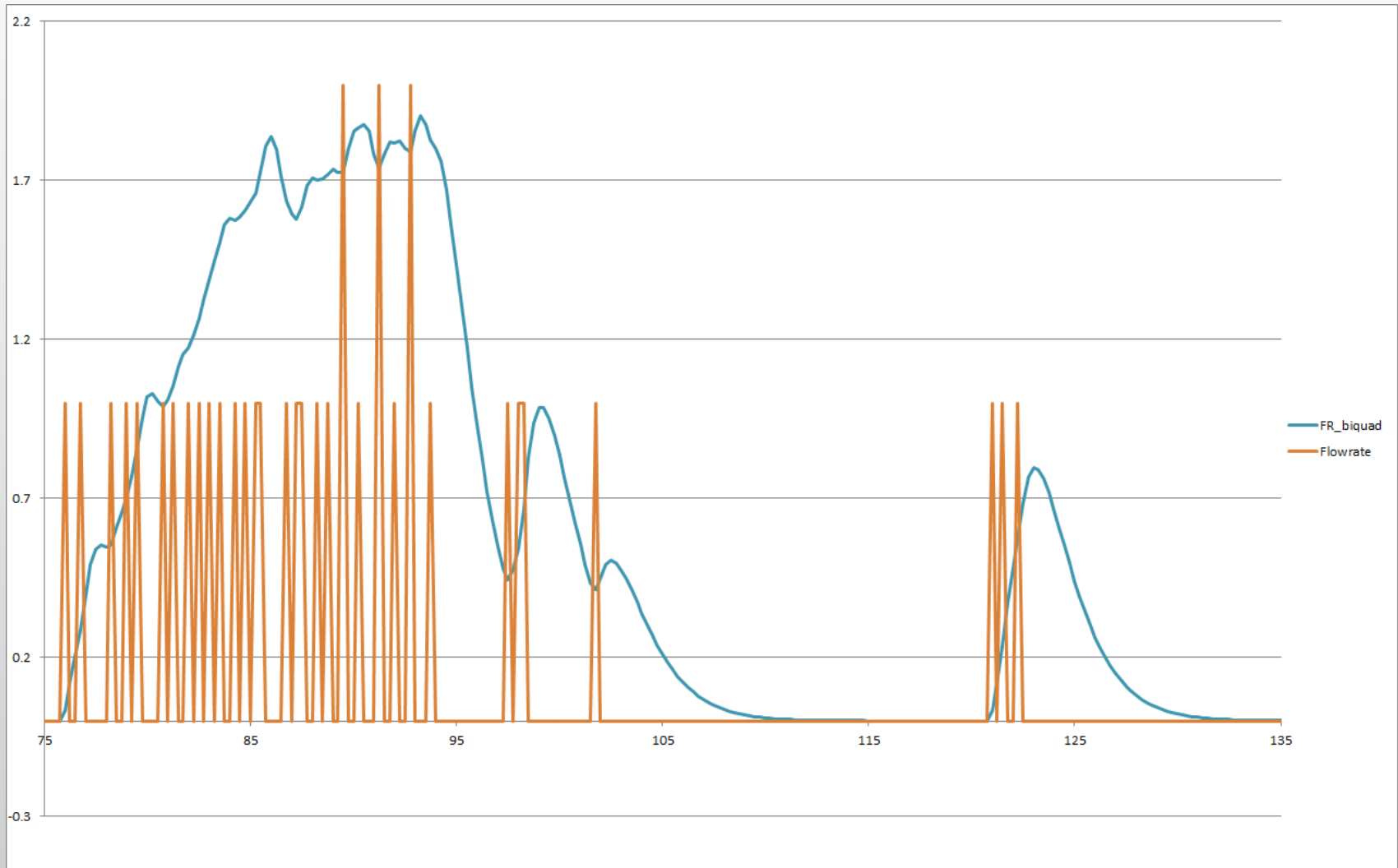
Proposed Solution

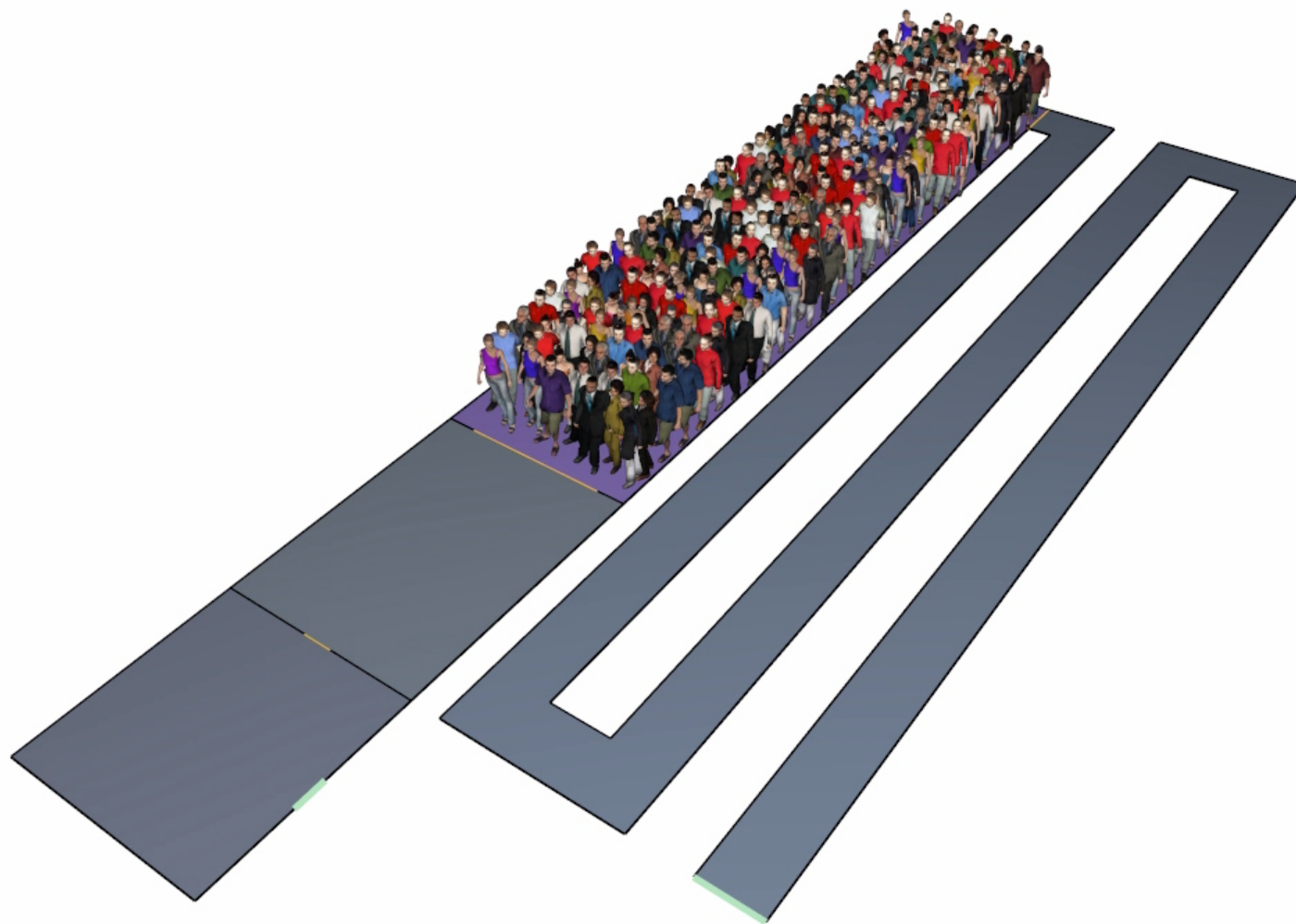


- Use actual door flowrates to estimate queue wait times

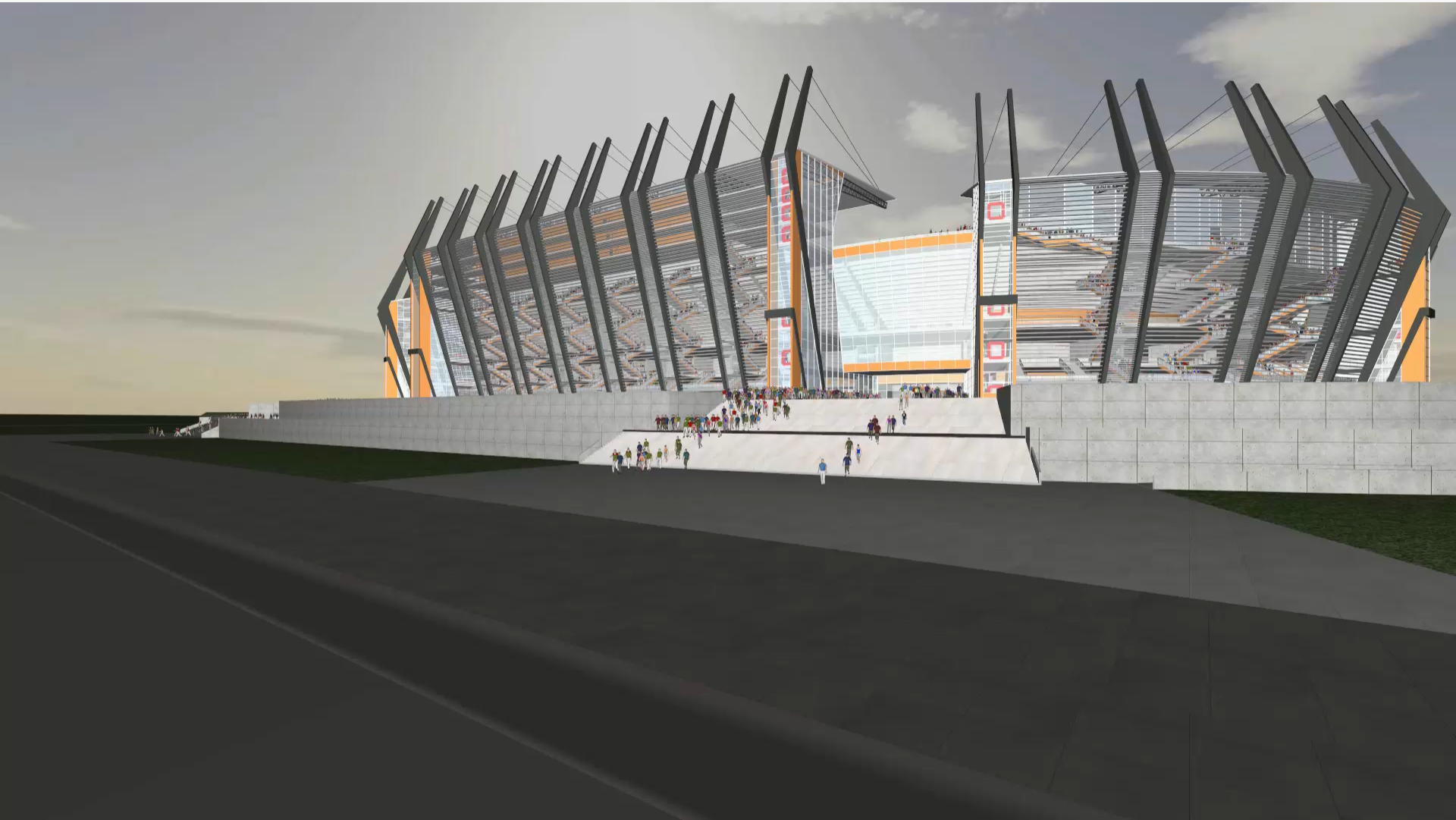


Low-Pass Filter





Stadium Evacuation

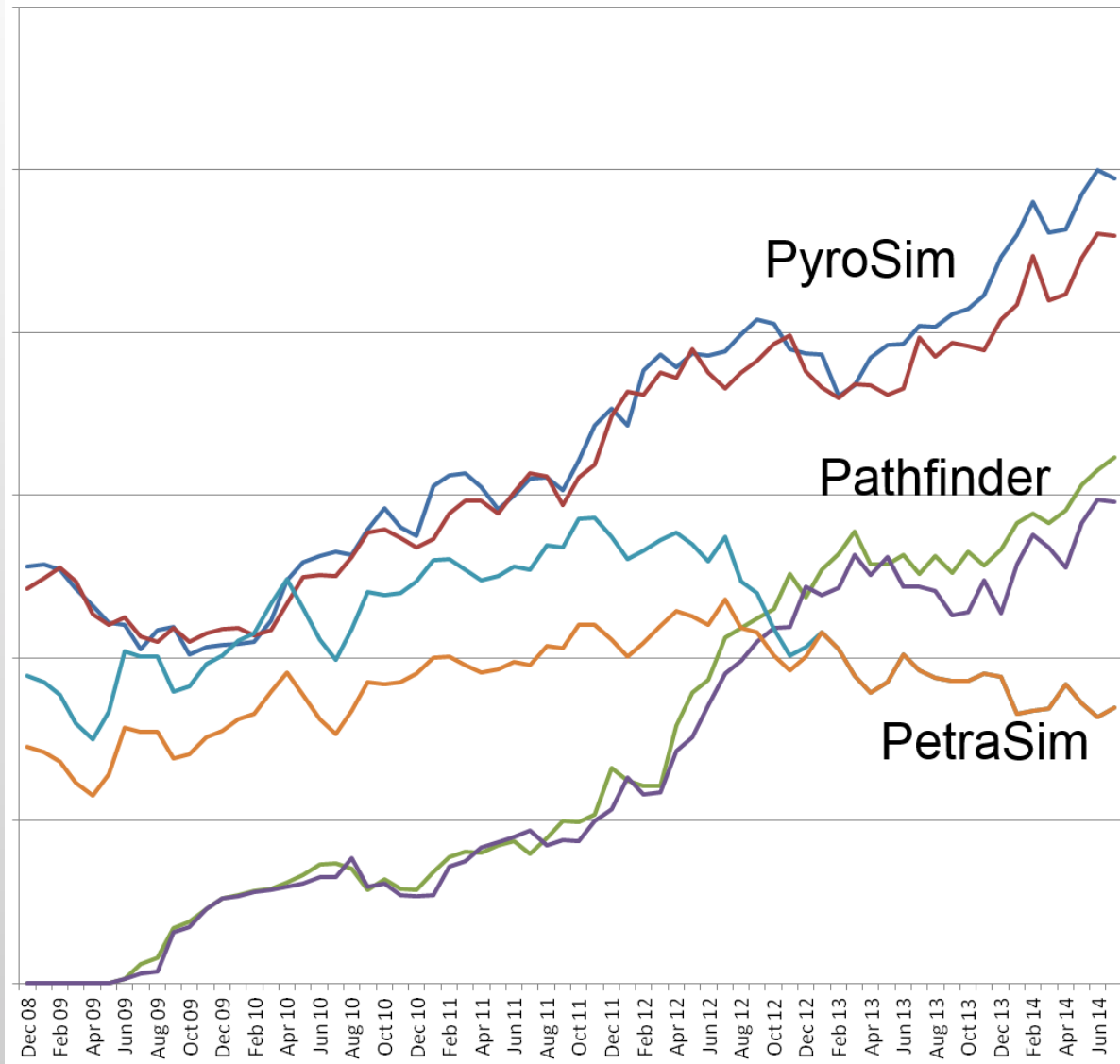


Company Philosophy



- Run the company as though all staff were shareholders
- Decent wages
- 15-20% retirement benefits
- Healthcare
- At the end of year, we share the profit
- Sustainable work loads

Sales



Challenges



- Competition from Revit or Hughes/RJA
- Transfer Swenson stock to selected employees
- Diversity in hiring
- Kansas politics
 - Remote workers
- We will be hiring in near future

Thank you

