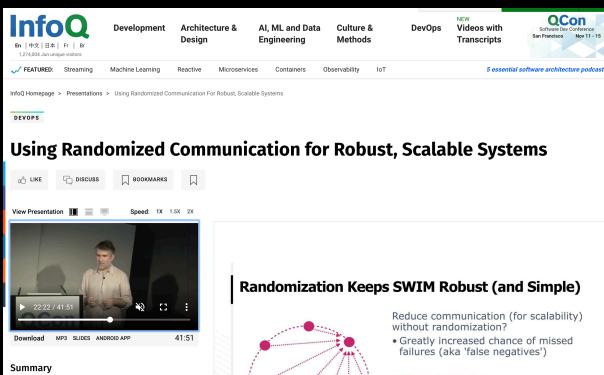
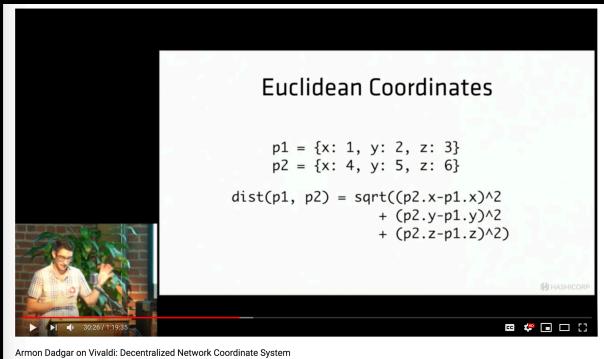




Research as Code

We Talk A Lot About Our Use of Research



InfoQ

Development Architecture & Design AI, ML and Data Engineering Culture & Methods DevOps Videos with Transcripts

FEATURED Streaming Machine Learning Reactive Microservices Containers Observability IoT

InfoQ Homepage > Presentations > Using Randomized Communication For Robust, Scalable Systems

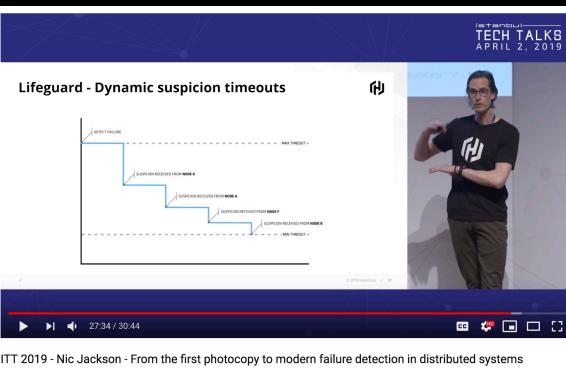
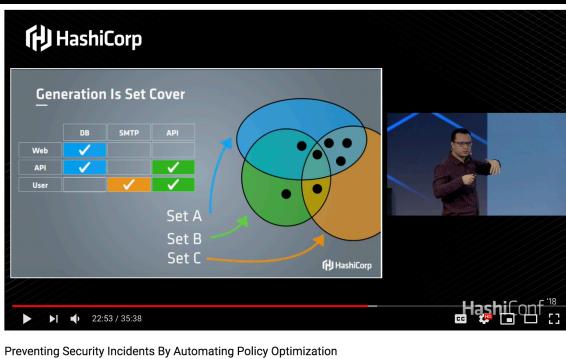
DEVOPS

Using Randomized Communication for Robust, Scalable Systems

Randomization Keeps SWIM Robust (and Simple)

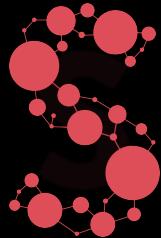
Reduce communication (for scalability) without randomization?

- Greatly increased chance of missed failures (aka 'false negatives')





Consumed Research Since Day 1



Serf

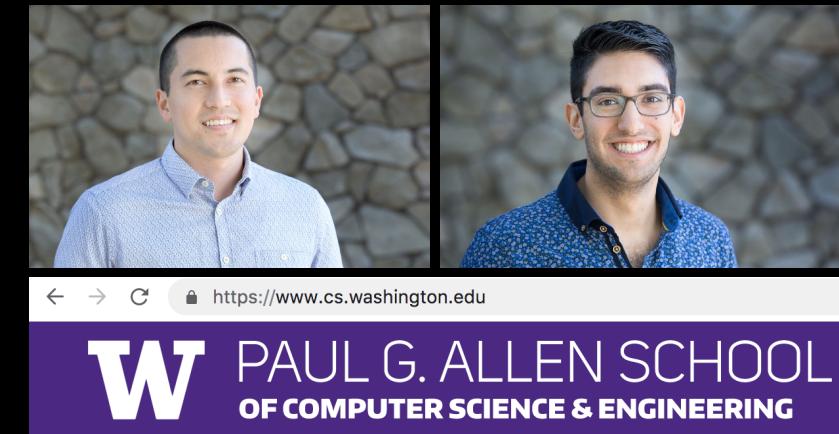
The screenshot shows a GitHub repository page for 'hashicorp/memberlist'. At the top, there are navigation links for 'Code', 'Issues 37', 'Pull requests 10', 'Actions', 'Projects 0', 'Wiki', 'Security', 'Insights', and 'Settings'. Below these are buttons for 'Watch', 'Star', 'Fork', and '237'. A dropdown menu shows 'Branch: master'. Underneath, a section titled 'Commits on Sep 9, 2013' lists two commits:

- 'Adding a gitignore file' by armon committed on Sep 9, 2013. It has a diff icon, a commit hash '9928b17', and a copy icon.
- 'Initial commit' by armon committed on Sep 9, 2013. It has a diff icon, a commit hash '1a09a04', and a copy icon.

Chose to implement **SWIM** ...

But only after careful evaluation of **Plumtree**, **T-Man** and **HyParView**

Valued Research Since Way Before Day 1



Retaining Sandbox Containment Despite Bugs in Privileged Memory-Safe Code

Justin Cappos, Armon Dadgar, Jeff Rasley, Justin Samuel, Ivan Beschastnikh, Cosmin Barsan, Arvind Krishnamurthy, Thomas Anderson

Department of Computer Science and Engineering
University of Washington
Seattle, WA 98195
{justinc,armond,jeffra45,jsamuel,ivan,cosminb,arvind,tom}@cs.washington.edu

Abstract

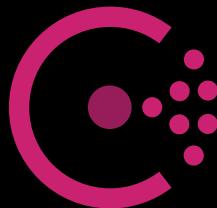
Flaws in the standard libraries of secure sandboxes represent a major security threat to billions of devices worldwide. The standard libraries are hard to secure because they frequently need to perform low-level operations that are forbidden in untrusted application code. Existing designs have a single, large trusted computing base that contains security checks at the boundaries between trusted and untrusted code. Un-

1. INTRODUCTION

Programming language sandboxes, such as Java, Silverlight, JavaScript, and Flash, are ubiquitous. Such sandboxes have gained widespread adoption with web browsers, within which they are used for untrusted code execution, to safely host plug-ins, and to control application behavior on closed platforms such as mobile phones. Despite the fact that program containment is their primary goal, flaws in



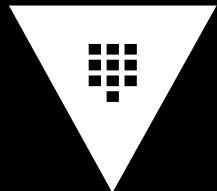
HashiCorp ❤ Research!



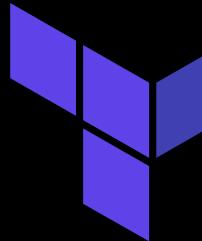
- Consensus (Raft)
- Gossip (SWIM, Lifeguard)
- Lamport and Vector Clocks
- Multi-Version Concurrency Control (MVCC)
- Network Coordinates (Vivaldi & follow ups)



- Scheduler Design (Mesos, Borg, Omega)
- Bin Packing
- Pre-emption
- Randomized choice



- Secure Authentication (Kerberos)
- Security Protocols
- Capability-Based Security
- Access Control Management
- Cryptography



- Graph Theory
- Type Theory
- Automata Theory

Use of Research Matured With Projects



Initial Release

- Evaluate multiple research solutions
- Choose one as base technology

Increasing Adoption

More Real-World Scenarios

Larger Scale Deployments

Add more technologies

Combine technologies

Adapt and extend technologies



"Time To Give Back"

Focus on **industrial** research,
working 18 to 24 months ahead of
engineering, on **novel** work

HashiCorp Research Charter



Academic Research Requirements



For peer-reviewed publication, a paper must

- Make a *novel* contribution to literature
- Consider *all* relevant prior work
- Adhere to The Scientific Method

Industrial Research Requirements



Efficiently discover relevant research,
for active and potential projects

Evaluate research against our users' actual needs

Enable other teams (especially Engineering)
to participate while doing their "day job"

Our Approach: "Research as Code"



Adopt core DevOps and agile practices

- Immutable (versioned) artifacts
- Backlog+iteration

Share engineering tools and processes

Foster a culture of research consumption



Efficient Research Discovery

Research Runs on Citations (and References)



I. INTRODUCTION

Group membership is an intuitive abstraction that can be used to address discovery, failure detection, and load balancing of components of a distributed system. SWIM [1] is a group membership protocol with a simple peer-to-peer design. Its use of randomized communication make it highly scalable, robust to both node and network failures, and easy to manage.

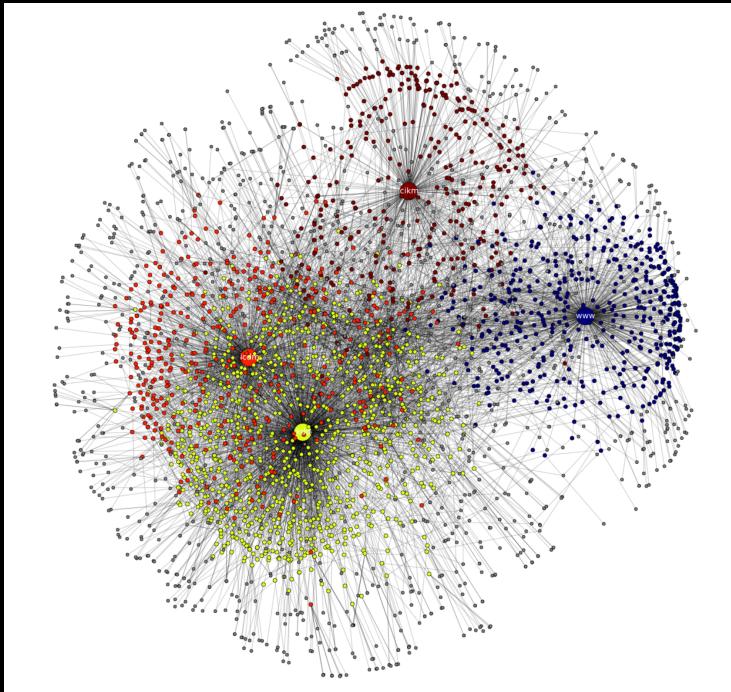
We are aware of three mature open source implementations of SWIM. Butterfly [2] is part of Habitat [3], a popular software automation platform. Ringpop [4] was built to support the applications of a global transportation technology company. memberlist[5] is our implementation of SWIM, which underpins Consul[6], a popular service discovery and management tool, and Nomad[7], a high-availability, data center scale scheduler. Through our relationship with customers, we know of hundreds of thousands of running instances of Consul, and deployments with more than 6,000 members in a single group.

REFERENCES

- [1] A. Das, I. Gupta, and A. Motivala, "SWIM: Scalable Weakly-consistent Infection-style Process Group Membership Protocol," in *Proceedings of the 2002 International Conference on Dependable Systems and Networks*, ser. DSN '02.
- [2] (2017, Nov.) Butterfly documentation. Chef. [Online]. Available: <https://www.habitat.sh/docs/internal/#supervisor-internals>
- [3] (2017, Nov.) Habitat. Chef. [Online]. Available: <https://www.habitat.sh>
- [4] (2017, Nov.) Ringpop documentation. Uber Technologies Inc. [Online]. Available: https://ringpop.readthedocs.io/en/latest/architecture_design.html
- [5] HashiCorp, "memberlist Project," <https://github.com/hashicorp/memberlist>, 2017, [Online; accessed 28-Feb-2018].
- [6] ———, "Consul Project," <https://www.consul.io/>, 2017, [Online; accessed 28-Feb-2018].
- [7] ———, "Nomad Project," <https://www.nomadproject.io/>, 2017, [Online; accessed 28-Feb-2018].
- [8] P. Huang, C. Guo, L. Zhou, J. R. Lorch, Y. Dang, M. Chintalapati, and R. Yao, "Gray failure: The achilles' heel of cloud-scale systems," in *Proceedings of the 16th Workshop on Hot Topics in Operating Systems*, ser. HotOS '17.
- [9] A. Demers, D. Greene, C. Hauser, W. Irish, J. Larson, S. Shenker, H. Sturgis, D. Swinehart, and D. Terry, "Epidemic algorithms for replicated database maintenance," in *Proceedings of the Sixth Annual ACM Symposium on Principles of Distributed Computing*, 1987.
- [10] A. Dadgar, J. Phillips, and J. Currey, "Lifeguard : Swim-ing with local health awareness," vol. abs/1707.00788, 2017. [Online]. Available: <http://arxiv.org/abs/1707.00788>



The Citation Graph



nodes == papers
edges == citations

Directed graph:
"Paper A cites (references) paper B"

Acyclic graph*:
A paper can only cite earlier papers
(*mostly)



"The citation graph is one of humankind's most important intellectual achievements"

*Dario Taraborelli,
Director of Research, the Wikimedia Foundation*

Price (Science, Vol 149, 1965)



Networks of Scientific Papers

The pattern of bibliographic references indicates the nature of the scientific research front.

Derek J. de Solla Price

This article is an attempt to describe in the broadest outline the nature of the total world network of scientific papers. We shall try to picture the network which is obtained by linking each published paper to the other papers directly associated with it. To do this, let us consider that special relationship which is given by the citation of one paper by another in its footnotes or bibliography. I should make it clear, however, that this broad picture tells us something about the papers themselves as well as something about the practice of citation. It seems likely that many of the conclusions we shall reach about the network of papers

chine-handled citation studies, of large and representative portions of literature, which are much more tractable for such analysis than any topical indexing known to me. It is from such studies, by Garfield (1, 2), Kessler (3), Tukey (4), Osgood (5), and others, that I have taken the source data of this study.

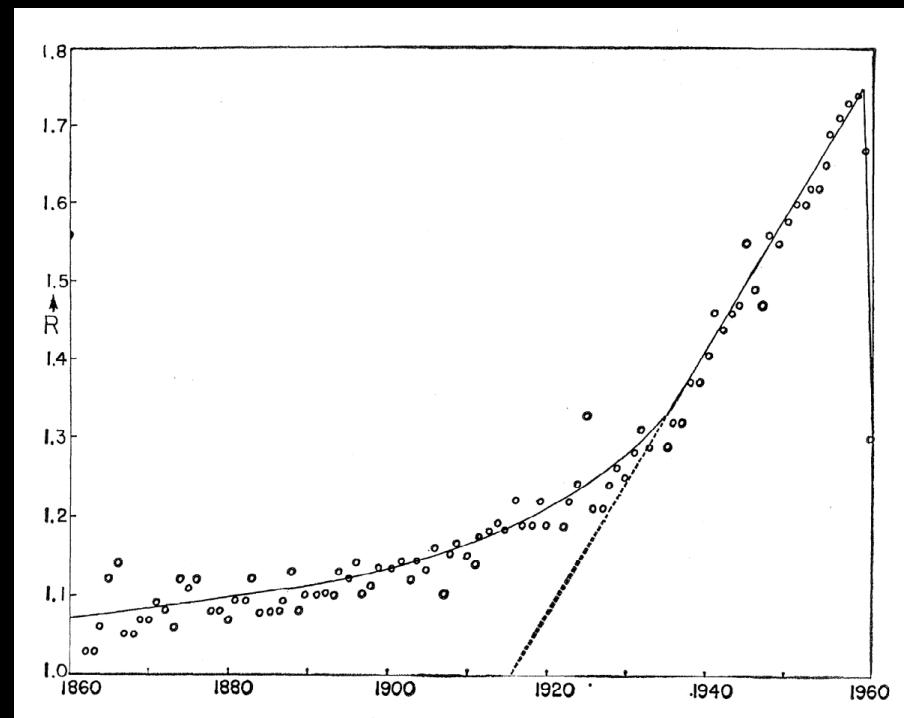
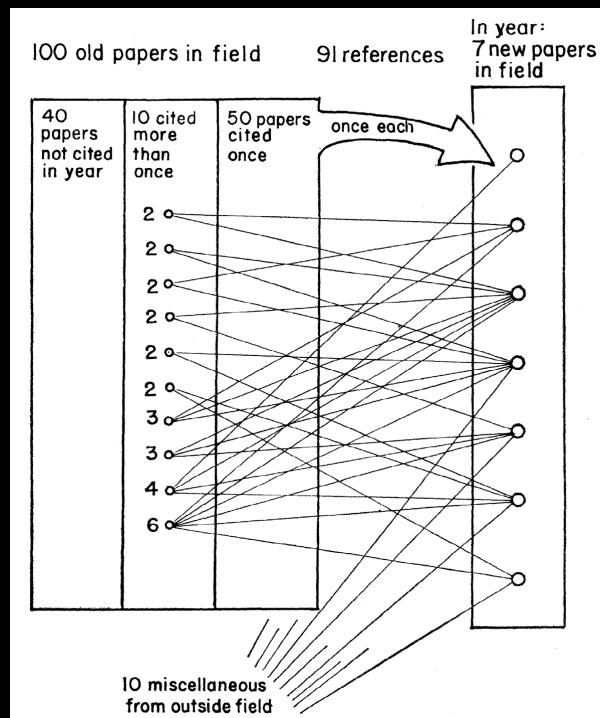
Incidence of References

First, let me say something of the incidence of references in papers in serial publications. On the average, there are about 15 references per paper

percent of the papers contain no references at all; this notwithstanding, 50 percent of the references come from the 85 percent of the papers that are of the "normal" research type and contain 25 or fewer references apiece. The distribution here is fairly flat; indeed about 5 percent of the papers fall in each of the categories of 3, 4, 5, 6, 7, 8, 9, and 10 references each. At the other end of the scale, there are review-type papers with many references each. About 25 percent of all references come from the 5 percent (of all papers) that contain 45 or more references each and average 75 to a paper, while 12 percent of the references come from the "fattest" category—the 1 percent (of all papers) that have 84 or more references each and average about 170 to a paper. It is interesting to note that the number of papers with n references falls off in this "fattest" category as $1/n^2$, up to many hundreds per paper.

These references, of course, cover the entire previous body of literature. We can calculate roughly that, since the body of world literature has been growing exponentially for a few centuries (6), and probably will continue at its present rate of growth of about 7 percent per annum, there will be about 7 new papers each year for every 100 previously published papers in a given

1965 Graph Visualization and Analysis





Use Diverse Discovery Methods

Querying and traversing The Citation Graph

Recommendation systems

Curated collections

Social recommendation



Research Resources... Live at the end of the talk

The screenshot shows a GitHub repository page for 'hashicorp/research-resources'. The repository is private. At the top, there are buttons for 'Configure Sourcegraph', 'Watch 0', 'Star 0', and 'Fork 0'. Below the header, there are tabs for 'Code', 'Issues 0', 'Pull requests 0', 'Actions', 'Projects 0', 'Wiki', 'Security', 'Insights', and 'Settings'. The 'Code' tab is selected. The main content area shows the 'research-resources / README.md' file. The file was last updated by 'bosconi' with commit 'e61ef59' 'now'. It has 1 contributor. The file size is 379 lines (9 sloc) and 2.55 KB. There are buttons for 'Raw', 'Blame', 'History', and file operations like 'Copy path', 'Find file', and delete. Below the file content, there is a section titled 'Research Resources' with a description: 'A collection of sites, papers and other resources that we hope will be of use if you are beginning to look at academic research.' There is also a 'Research Discovery' section and a 'Citations and References' section with detailed explanations of what citations and references are.

Research Resources

A collection of sites, papers and other resources that we hope will be of use if you are beginning to look at academic research.

Research Discovery

Citations and References

A citation is an external source of information that is mentioned ('cited') in the body of a paper ('in-text' or 'inline'). Usually, the style of the citation is terse, and may be enclosed in parentheses or square brackets. For example, a citation might look like this: [1] or this: (Kraiser, 2011). However, there are [many citation formats](#), and for papers that have been published after passing through a submission process, the format used is usually dictated by the rules for submission of the organization through which the paper was published.

A reference is a more full textual description of an external source, designed to allow the reader to obtain the referenced item as a primary source. References are typically collected in a list in a References or Bibliography section toward the end of the paper. Usually, every reference must have been cited somewhere in the paper, and usually every



Topics Covered

Research Discovery

How to Read and Evaluate a Paper

Methodological Problems

Tracking and Making Sense of It All



Open Access Please

Science

Contents ▾ News ▾ Careers ▾ Journals ▾

785

University of California boycotts publishing giant Elsevier over journal costs and open access

By Alex Fox, Jeffrey Brainard | Feb. 28, 2019, 7:00 PM

News in Europe

Elsevier's Open Access Controversy: German Researchers Resign to Register Protest

Last updated May 21, 2018 — 0



Use Diverse Discovery Methods

Querying and traversing The Citation Graph

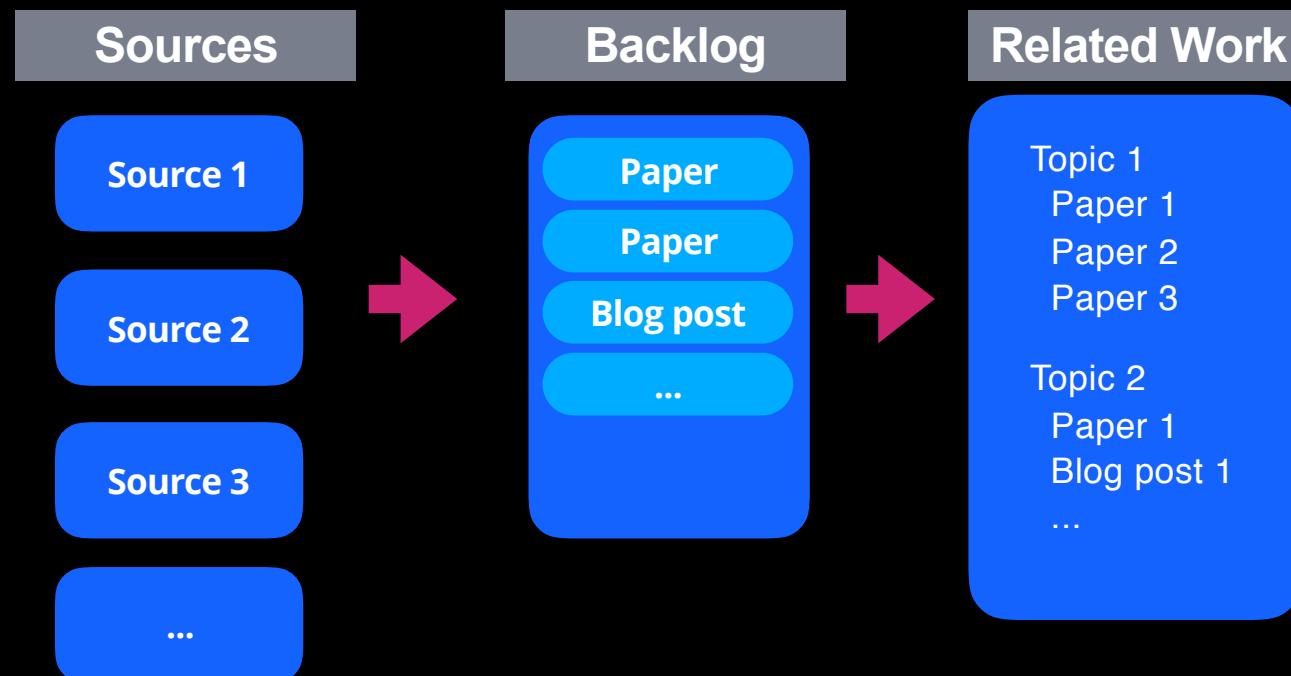
Recommendation systems

Curated collections

Social recommendation



Per-Project Related Work





Per-Project Related Work

The screenshot shows a Google Sheets document titled "Vault Advisor Related Work". The document has a single sheet with the following content:

Category	Source	Status	Links
Sources	ACM CCS	Done	<ul style="list-style-type: none">https://www.sigsac.org/ccs/CCS2019/https://www.sigsac.org/ccs/CCS2018/program/
	ACM AISEC Workshop	Done	<ul style="list-style-type: none">2018
	ACM EuroSec Workshop (Co-located with EuroSys)	Done	<ul style="list-style-type: none">EuroSec 2019EuroSec 2018
	IEEE DSA	Done	<ul style="list-style-type: none">https://paris.utdallas.edu/dsa18/
	Google	Done	<ul style="list-style-type: none">https://services.google.com/fh/files/misc/fleet_management_at_scale_white_paper.pdf
	Google Research	Done	<ul style="list-style-type: none">https://cloud.google.com/beyondcorp/#researchPapershttps://cloud.google.com/context-aware-access/
	USENIX Login	Done	<ul style="list-style-type: none">https://cloud.google.com/iam/
	USENIX SOUPS	Done	<ul style="list-style-type: none">https://cloud.google.com/iam/
	Backlog		
Topics	Modern Computer Security		
	OSS Systems		
	Commercial Systems		
	Other Policy-Oriented Research		
	Metrics		

Per-Project Related Work



The screenshot shows a Google Docs spreadsheet with the title "Vault Advisor Related Work". The spreadsheet has two main sections: "Backlog" and "Topics".

Backlog:

- Optimization-Based Network Flow Deadline Scheduling
 - Integer-programming based constraint solving

Topics:

Modern Computer Security

- Privileged Access Management for Active Directory Domain Services (MSFT docs)
 - PAM, RBAC ABAC
 - Vault as a security bastion
- Enforcing Privacy Policies with Meta-Code (Johansen et al, 2015)
 - Policy enforcement via code interposed in the filesystem access path.
- Paradigm Regained: Abstraction Mechanisms for Access Control (Miller and Shapiro, 2003)
 - Access is typically controlled only by manipulating a system's protection state—the arrangement of the access graph.
 - Capability systems have been proven unable to enforce some basic policies: revocation, confinement, and the “*-*properties”.
 - In actual practice, programmers build access abstractions—programs that help control access, extending the kinds of access control that can be expressed. When analysis includes the possibility of access abstractions, as it must, the original capability model is shown to be stronger than is commonly supposed.
- Identity Governance
 - <https://www.forbes.com/forbes-insights/our-work/identity-governance/>
 - “Almost half of data breaches originate from within an organization—and most of those events result from a failure to govern the digital identities of employees and other users, such as contractors, partners and even software bots.”
- RBAC v. ACL (NIST, 1997)
 - “A very simple RBAC model is shown to be no different from a group ACL mechanism from the point of view of its ability to express access control policy.”



Benefits of an Agile Approach

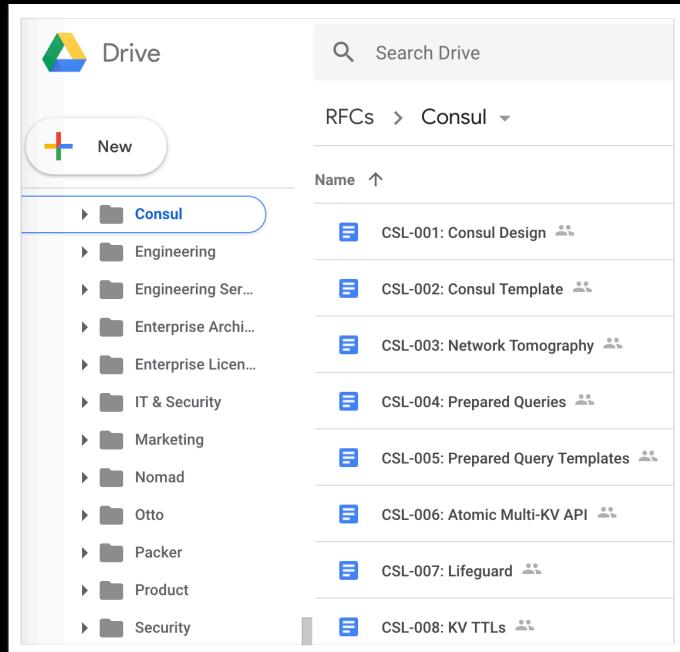
Backlog plus tracking of per-source progress
breaks the problem down

Small, achievable tasks encourage participation



Evaluating Research Against Users' Needs

Use Existing Processes and Artifacts



HashiCorp's Software Design Workflow

PRD Per-feature product requirements

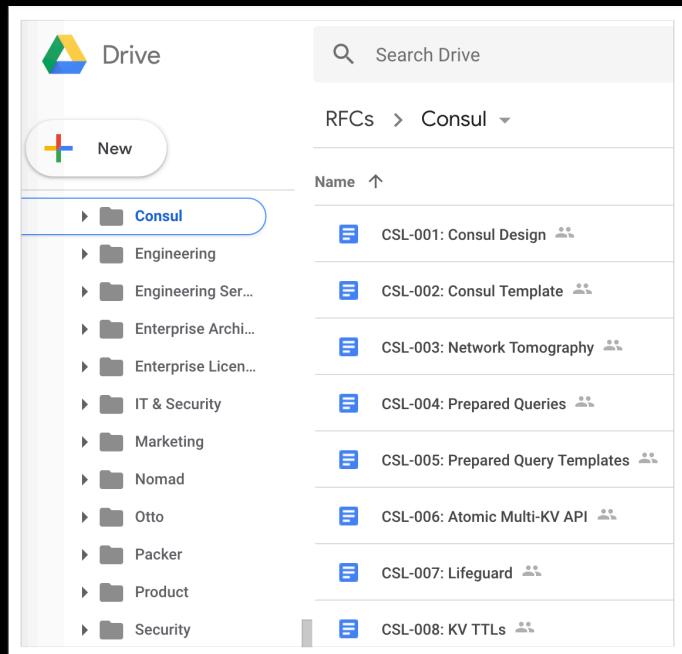
RFC Per-feature high-level design

Use same process and templates for research projects

Familiarity encourages cross-org collaboration



Embed Research Discussion in Product Workflow



Research section in Engineering docs, if relevant

- Backlog
- Features
- Pros and cons

c.f. Competitive analysis

A research project could *actually* become part of a competing product!



Reproducible Test Environments

hashicorp / consul-test-environments Private Configure Sourcegraph Unwatch 91 Star 0 Fork 0

Code Pull requests 1 Actions Projects 0 Security Insights Settings

Basic soak test environment for Consul testing using Nomad jobs. Edit

Manage topics

376 commits 5 branches 0 releases 7 contributors

Branch: master New pull request Create new file Upload files Find File Clone or download

File	Description	Time
jobs	remove some unnecessary optional params	2 months ago
packer	Allow Google AuthD users to be Editors so we can actually play with g...	29 days ago
terraform	Upgrade metrics to 0.12	29 days ago
.gitignore	ignore custom tf providers	2 months ago
README.md	Update README.md	2 months ago



Varied, Reproducible Workloads

Screenshot of the GitHub repository `hashicorp / consul-live`. The repository is private and has 98 commits, 3 branches, 0 releases, and 5 contributors. The latest commit is `f66821b` on May 14. A blue circle highlights the commit `commands`.

File	Description	Time
<code>commands</code>	Improve usability for testing upgrades	2 months ago
<code>hive</code>	Improve usability for testing upgrades	2 months ago
<code>vendor</code>	Improve usability for testing upgrades	2 months ago
<code>.gitignore</code>	add a basic makefile	last year
<code>LICENSE</code>	Initial commit	4 years ago
<code>Makefile</code>	Improve usability for testing upgrades	2 months ago
<code>README.md</code>	Initial test - perform writes at increasing rate	last year
<code>main.go</code>	Initial test - perform writes at increasing rate	last year

Cross-Team Artifact-Driven Approach



Any team can contribute, use or review a new test tool or workload

- Engineering, Research, Advocates, Sales Engineering, Customer Success, Solutions ...

Research benefits from workloads that reflect real use cases

Research contributes **new metrics, test methodologies and workloads**, that can be used to improve the product



Enabling Cross-Team Research Collaboration

Internal Research Discussion Forum



#team-research

☆ | 73 | 1 | Add a topic

Wednesday, November 6th

10:41 AM cgbaker anybody going to/tracking this: Fourth ACM/IEEE Symposium on Edge Computing
<http://acm-ieee-sec.org/2019/index.php>

10:56 AM jc @cgbaker, on my tracking list.
Good overlap of the PC etc with HotEdge and HotMobile, which I have been following: <https://www.usenix.org/conference/hotedge19/workshop-program>
<http://www.hotmobile.org/2019/index.php?id=program>

 USENIX
HotEdge '19 Workshop Program
The 2nd USENIX Workshop on Hot Topics in Edge Computing (HotEdge '19) will be co-located with USENIX ATC '19 and will take place July 9, 2019, at the Hyatt Regency Lake Washington in Renton, WA.
Apr 30th (36 kB) ▾

Interesting keynote at the top of this page:
<http://acm-ieee-sec.org/2019/keynote%20and%20panel.php>

" Far Edge and smaller Data Centers (Edge DC) will become the Key delivery vehicle for workloads rather than big data center clouds at limited locations in the service/cloud providers network. In order to enable easy access to latency sensitive applications micro Data Centers will spawn over different locations. This also open up a whole new model of delivering apps and services in sparsely connected geo locations where infrastructure such as smart cities etc. is not possible. Another challenge is to consolidate multiple architectures and implementations in the industry and open source to an optimal and flexible Infrastructure. This infrastructure also needs to be scalable enough to distribute functions to serve billions of parallel devices and tasks at the edge. This talk will talk about the various Open source efforts in the edge space"

I still need to check out the new MSFT stuff that [@Mishra](#) reported on by email last Friday (OAM, Rudr, Dapr) and connect the dots to the prototype opportunity with

Knowledge Sharing - Any Which Way



#talk-mathematics

☆ | 8 11 | 0 | Add a topic

Friday, October 11th

8:57 AM jc Has anyone found good remote white board collaboration software? I'd be open to buying an iPad + pen if it made that viable. I took a quick look a while ago, but none of the offerings looked that compelling. Or they wanted a pricey per user monthly fee. (Not that I should grumble too much about people trying to monetize software!)

jc 4 replies Last reply 1 month ago

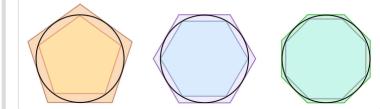
2:28 PM jc @TRex, this looks interesting: <https://explaineverything.com/the-magic-of-explain-everything/>

2:28 PM And you get to do 3 projects for free...
I'd like something that works with laptop and tablet ideally. But if I have to choose, its laptop. I have a Wacom tablet, and can use that for input.

Tuesday, October 29th

9:40 AM lang <https://medium.com/cantors-paradise/uncomputable-numbers-ee528830d295>

M Medium
Uncomputable Numbers
Real numbers we can never know the value of
Reading time
15 min read
Sep 5th (105 kB) ▾



Friday, November 8th

12:26 PM lang <https://arxiv.org/abs/1911.02226>

arXiv.org
Mathematics underfoot: The formulas that came to Wuerzburg from New Haven
Two formulas are set in floor-tiles in the foyer of the Wuerzburg building that houses the laboratory in which Wilhelm Roentgen discovered X-rays in 1895. But what do they mean, and what have they...
another basically off-topic one :)

Today

Sponsorships and Memberships



Association for
Computing Machinery



Brownbags and Lightning Talks



Drive

Search Drive

Engineering > Brown Bags

New

Shared drives

- Atlantis
- Cloud Platform
- Consul
- Customer Success, W...
- Developer Relations
- Education
- Engineering
 - Brown Bags
 - 2016-11-15-s...
 - 2016-12-06-a...
 - 2016-12-20-s...
 - 2017-01-31-p...
 - 2017-02-14-a...
 - 2017-06-27-jo...
 - 2017-08-08-c...
 - 2017-08-22-...
 - 2017-09-12-cl...
 - 2017-10-10-e...
 - 2017-12-12-p...
 - 2018-01-09-p...
 - 2018-02-20-

SHAMIR'S SECRET SHARING

Using only high-school maths*

* mostly

A screenshot of a presentation slide. The title is "SHAMIR'S SECRET SHARING". Below the title, it says "Using only high-school maths*". At the bottom right, there is a small note "* mostly". In the top right corner of the slide, there is a video feed showing a person with curly hair, identified as Paul Banks. The video feed has a yellow border and is labeled "Paul Banks".



But Enough About Us ...

You Can Do This!



Even without a dedicated research team

Apply agile and lean techniques you know

- backlog + iteration
- immutable artifacts

Culture of collaborative research consumption

Benefits of Research (Tell Your Boss ...)



State-of-the-art algorithms

Better metrics, workloads and test methodologies

Talent

- Interns and full-time

Reputation

- External: Customers and potential customers
- Internal: Employee satisfaction



Where to Begin?

Papers We Love (PWL)

– Github repo + Meetups + YouTube + Conference

Papers We LoveSM *f(x)=x*

The Morning Paper (TMP) by Adrian Colyer

– Blog + email

the morning paper

a random walk through Computer Science research, by Adrian Colyer

At work

- Slack channel, reading group, brownbags, lightning talks
- Colleagues with research experience?
- Collaborate with your Data Science team?

Getting Involved in Research



Ask researchers questions

– Email, Twitter

Attend academic conferences

Discuss your open problems

– Blog
– Twitter



PhD Candidate Interns

Mutual benefit

- Your (relevant) problem/data == a **goldmine** for their work
- Work done during internship is your company's Intellectual Property

Approach students and advisors

- Poster sessions at conferences
- Email



Researchers are People Too!

Sarah Knowles
@dr_know

Follow

Is it genuinely a thing that ppl don't email academics for their papers because they think we get paid for them?

We actually pay to make them free (I'd try to explain this but it's... a mess.) And we're happy and allowed to distribute copies. Hit us up!

5:31 AM - 9 Feb 2019

1,540 Retweets 4,772 Likes

88 1.5K 4.8K

Tweet your reply

Madelon @m4delen - Feb 9
Replies to @dr_know @BipolarBlogger
Yes. I am always too shy to email researchers when it says email researchers for a copy. I worry they will be annoyed and think 'I am a very busy researcher why does this person think I have time to email out copies to random strangers'.

11 2 105

Sarah Knowles @dr_know - Feb 9
Most researchers reaction would be "😍😍 a random stranger wants to read my stuff!"

5 6 251

Sarah Knowles @dr_know · Feb 9
Most researchers reaction would be "😍😍 a random stranger wants to read my stuff!"

5 6 251

Rheumatoid Patient @rheumpatient · Feb 10
Yep, please read my stuff I spent hours working on and writing up!

1 18

Dr. David Mills @DTL · Feb 9
Replying to @dr_know
I'm more than happy to email out copies of my work, but there are papers I don't even have a copy of now and can't access because we don't subscribe to the journal.
Thankfully sci-hub has most of them.

23

GeePaw Hill @GeePawHill · Feb 10
Replying to @dr_know
not to mention that *actual* *interest* in one's work usually makes one's day. i've written many scholars over the years. never found them to be anything but gracious and grateful and helpful, about reprints or anything else.

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github.com/hashicorp/research-resources

PRs welcomed.

Thank You!