Optimal Domain-Based Stratified Sampling Allocations Developed in RShiny

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Opinions are those of the Author and do not necessarily represent the Defense Department

RSSC

- Defense Research, Surveys and Statistics Center
- Responsible for conducting large scale, cross-component military surveys
  - Congressionally mandated surveys
  - Policy makers
- Ex: Don’t Ask Don’t Tell (2010), Workplace Gender Relations

Presentation Overview

- Introduce sampling tool objective problem
- Optimization math using Chromy (fast)
- Overview of process
- Sampling Tool Demo slides
- Future Roadmap

Sampling Tool Objective

- Develop a sample allocation for complex surveys capable of meeting various precision constraints (MoEs) for many domains of interest (E.g. Army estimate, Male estimate)
  - Ex: “Do you plan to re-enlist?”
- Goal: Minimize cost (and burden), Maximize precision
  - Make the most precise estimate for the lowest cost
- Problem: Conceptually straightforward, but can lead to challenging optimization problems

Domain-Based Sampling

- Domains are subsets of the population
- Examples of active duty military domains include:
  - Service type: Army (N=500,000), Navy (N=300,000), etc.
  - Crossings of Domains:
    - Overseas x Asia Deployment (N = 91,000)
    - Marine Corps x Sr. Officers (N=7,000)
- Typical omnibus military survey, “Status of Forces”, has > 70 domains

Chromy Optimization

- Multiple Constraint (Domains) Problem
- Minimize Cost:
- $Cost = \sum_{h=1}^{H} C(h)x(h) + C_o$

- Subject To:
- $\sum_{h=1}^{H} \frac{V(k,h)}{x(h)} \leq V(k)^*$

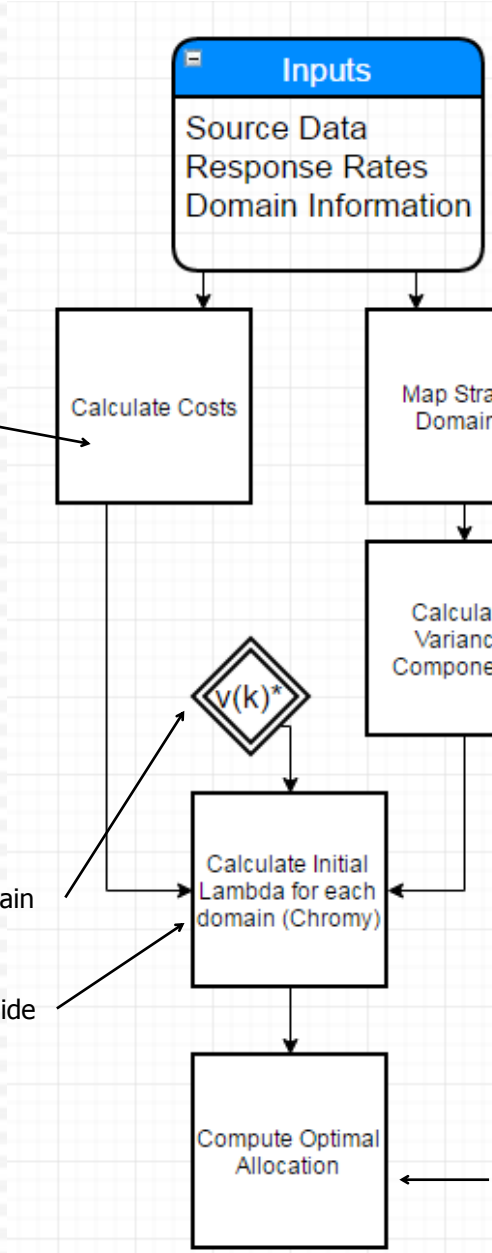
Chromy Optimization (contd)

- Treating as equality constraint
- $\lambda(k) = \sum_{h=1}^{H} C(h)x(h) + \sum_{k=1}^{K} \lambda(k) \sum_{h=1}^{H} \left(\frac{V(k,h)}{x(h)} - V^*(k) \right)$
- $\frac{d\lambda}{dx(h)} = C(h) + \lambda \left(\frac{-V(k,h)}{x(h)^2} \right)$
- Algebraically:
- $x(h) = \left[\lambda \frac{V(k,h)}{C(h)} \right]^{\frac{1}{2}}$

Chromy Optimization (contd)

- Substitute $x(h)$ back into constraint:
- $V(k)^* = \sum_{h=1}^{H} \frac{V(k,h)}{x(h)} = \sum_{h=1}^{H} \frac{V(k,h)}{\left[\lambda \frac{V(k,h)}{C(h)}\right]^{\frac{1}{2}}}$

- Result from Chromy (pg. 197):
- $\lambda(k) = \sum_{h=1}^{H} \left[\frac{V(k,h)C(h)}{V(k)^*}\right]^2$



Inputs: Discussed Next

Source Data x Domain Information

Discussed soon!

Response Rates
For each strata

Math Details:
Covered later but brief

Constraint For Domain

Previous Slide

Result we want to obtain, through iteration

Input Files: Source Data

Strata Variables

Domain Variables

Count: # of people

Row#	Service	Paygroup	Gender	Race	CONUS	BAH	Marital	Education	Enlisted	Count	Strat
1	1	1	1	1	1	0	0	1	1	5	1
2	1	1	1	1	1	0	1	1	1	2	1
3	1	1	1	1	1	0	0	1	1	18	1
4	1	1	1	1	1	1	1	1	1	143	1
5	1	1	1	1	2	0	0	1	1	10	2
	…	…	…	…	…	…	…	….	…	…	..
52K	4	5	2	2	3	1	1	4	0	12	200

143 People have these attributes:
1,1,1,1,1,1,1,1,1

Strata variable

- File from DoD Mainframe, crossing of every variable resulting in a Count in variable format: Variable Service, Level 1 = Army, Level 2 = Navy, etc.

- Row 4:
- Army x Jr-Enlisted x Male x Non-Minority x US x On Base x Married x HS

Input Files: Domain File

Domain	DomVar1	Level	DomVar2	Level	V*(k): Precision
Army	Service	1			0.05
Navy	Service	2			0.05
…					
E1-E4 (Jr. Enlisted)	Paygrade	1			0.05
E5-E9 (Sr. Enlisted)	Paygrade	2			0.05
…					
O4-O6 (Sr. Officer)	Paygrade	5			0.05
…					
Army * Enlisted (Jr. & Sr. Enlisted)	Service	1	Paygrade	1 & 2	0.05
…					
Single	Marital	0			0.05

Input Files: Response Rates

From Historical Surveys / Modeling / some guessing

Strata	Predicted (Historical) Response Rate	Eligibility Rate
1	0.12	0.98
2	0.15	0.98
3	0.09	0.99
4	0.14	0.99
…		
199	0.40	0.99
200	0.42	0.99

Most people eligible

Survey time of fielding lag ~ people leave, etc.

Making a Stratum Domain Map

Service	Paygroup	Gender	Race	CONUS	BAH	Marital	Education	Enlisted	Count	Strata
1	1	1	1	1	0	0	1	1	5	1
1	1	1	1	1	0	1	1	1	2	1
1	1	1	1	1	0	0	1	1	18	1
1	1	1	1	1	1	1	1	1	143	1

Pretend this is "entire" Stratum 1:
5+2+18+143 = 168

Strata x Domain

Strata	Domain	Domain Variable (CODE)	Strata-Dom Count
1	Army	Service =1	5+2+18+143 = 168
1	Navy	Service = 2	0
1	E1-E4 (Jr. Enlisted)	Paygroup = 1	168
1	E5-E9 (Sr. Enlisted)	Paygroup = 2	0
1	O4-O6	Paygroup = 5	0
1	Army*Enlisted	Service = 1 AND Paygroup = (1,2)	168
1	Single	Martial = 0	5+18 = 23
2	Army	Service = 1	…
…	…	…	…
Last Strata	Last Domain	…	…

Stratum Domain Map in R

- R pseudo code:

```
for(i in 1:length(DOMAINS)){
  single_domain<-SOURCE_DATA %>%
    group_by(STRATA) %>%
    filter_(eval(DOMAINCRITERIA[i])) %>%
    summarise(strdomsize=sum(COUNT))
  strdomcnt<-rbind(strdomcnt,cbind(single_domain,domain=i))
}
```

- Essentially:
  - For first to last domain; From the Source Data file;
  - For each STRATA;
  - Subset the Data to look at only 1 particular domain [i];
    - Such as SERVICE = 1 or MARITAL = 0 … or SERVICE = 1 & MARTIAL = 0!
  - Add up the number of individuals (sum); Store result;
  - Iterate

Stratum Domain Map (Contd)

- This type of mapping exists for Every Strata x Every Domain.
- A survey with 200 strata and 70 domains will have up to 14,000 Stratum-Domain mappings
  - Fewer in practice: can safely drop the 0's and stratification does a good job
- Can compute high value strata for certain domains

Cost Model Calculations

- How much does it cost to get a response?
- Example

Strata	Predicted (Historical) Response Rate	Eligibility Rate
1	0.123	0.98

Most people eligible

Low Response Rate

- $C(h) = C\left(\frac{1}{RR*ER}\right) + C_o$
- $C(1) = C\left(\frac{1}{0.123*0.98}\right) + C_o = \sim 9C + C_o$

For every 9 people we sample,
Expect 1 respondent

Variance Calculations

- Domain Variance – From Mason (1995)
- $Var(k,h) = \sum_{h=1}^{H} \left(\frac{N_h}{N_k}\right)^2 \left(\frac{N_h - n_h}{n_h - 1}\right) \left(\frac{p(1-p)}{n_h}\right)$

- Domain Variance (k) Compared to Constraint (k*):
- $Var(k) \leq Var(k^*)$

- Main takeaway: Variance of the domain is related to

Lambda Development

$$\lambda(k) = \sum_{h=1}^{H} \left[\frac{V(k,h)C(h)}{V(k)^*}\right]^2$$

- Quick Review: Lambda is based on Variance, Cost and Constraint
- The initial lambda will dictate some x(h)
- Update lambda based on allocation
- As x(h) increases, v(h) should get closer to V*(k)

Algorithm

- For each strat-domain
- Assign x(h) based on lambda
- Calculate expected domain variance based on all h
- Compare domain variance to constraint
- Update lambda based on how far we are!
- Iterate until we're done
- Mainly working to solve second order interactions as main domains will be optimized by coincidence
  - If we can solve Army x Enlisted x Male, we probably have already solved Army and Enlisted… and Male!
- x(h) is constrained by:
  - Size of strata

Sampling Tool with R & Rshiny

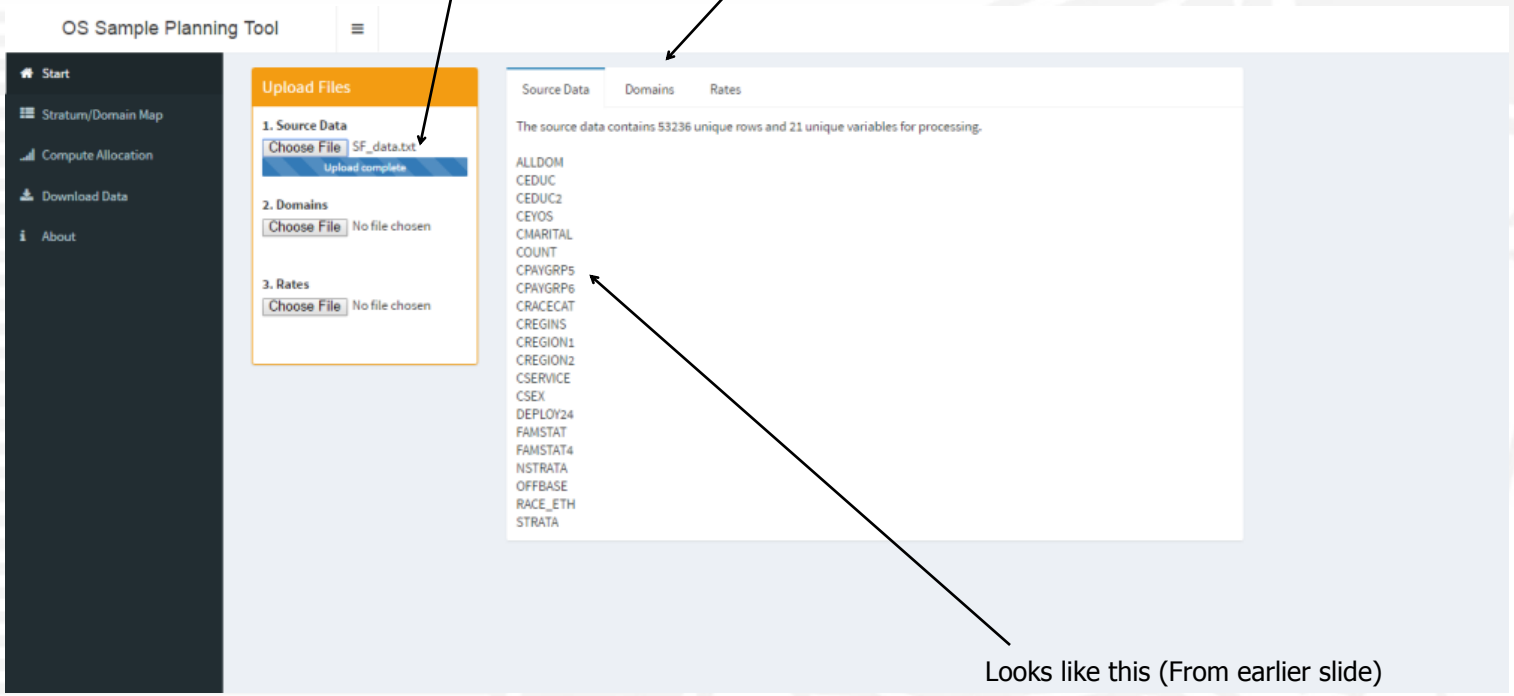
- Developed in R
  - Open source, been around since 1993
- Code re-written into R Shiny
- Shiny is an interactive web application for R
  - Lots of examples: Showmeshiny.com
- Essentially running R on the web
- Deployed to a Shiny server
  - Can be run offline for privacy concerns / private Rshiny

Sampling Tool Demo

Easily read data

Multiple Tabs

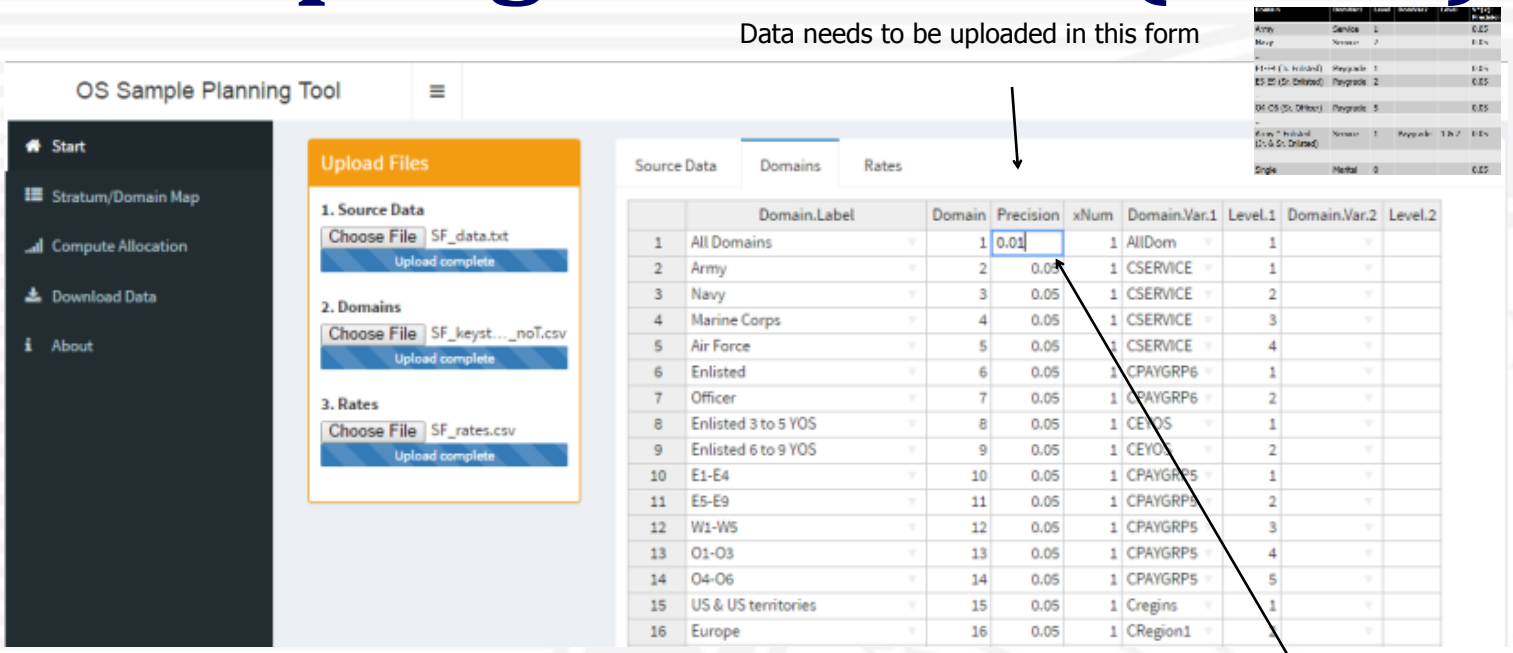
Menus



Looks like this (From earlier slide)

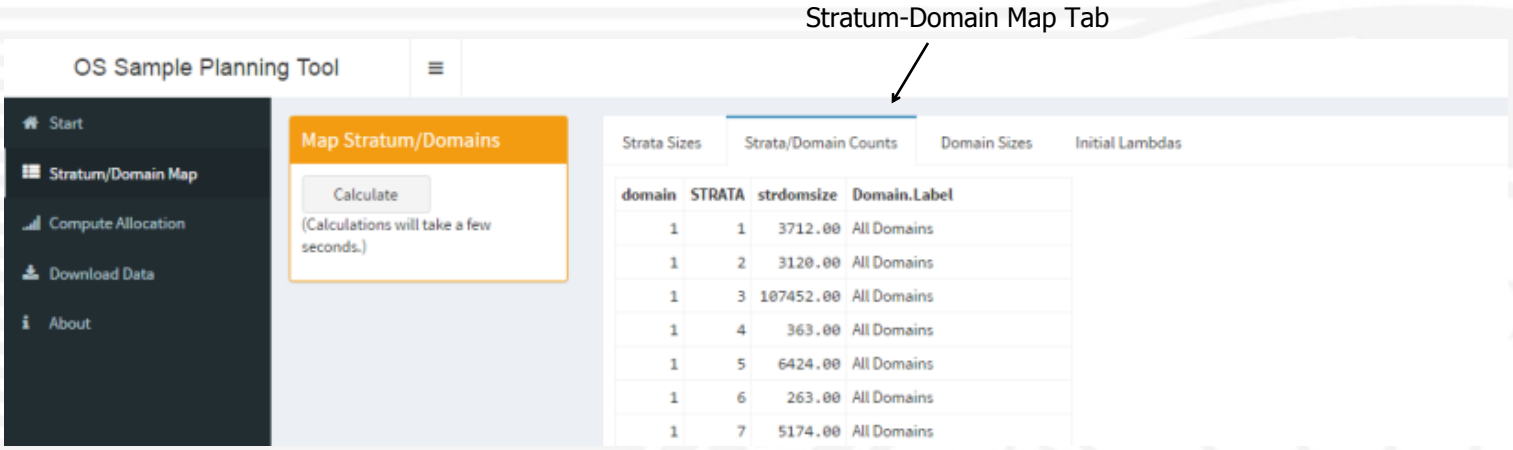
Row#	Service	Paygroup	Gender	Race	CONUS	BAH	Marital	Education	Enlisted	Count	Strata
1	1	1	1	1	1	0	0	1	1	5	1
2	1	1	1	1	1	0	1	1	1	2	1
3	1	1	1	1	1	0	0	1	1	18	1

Sampling Tool Demo (contd)



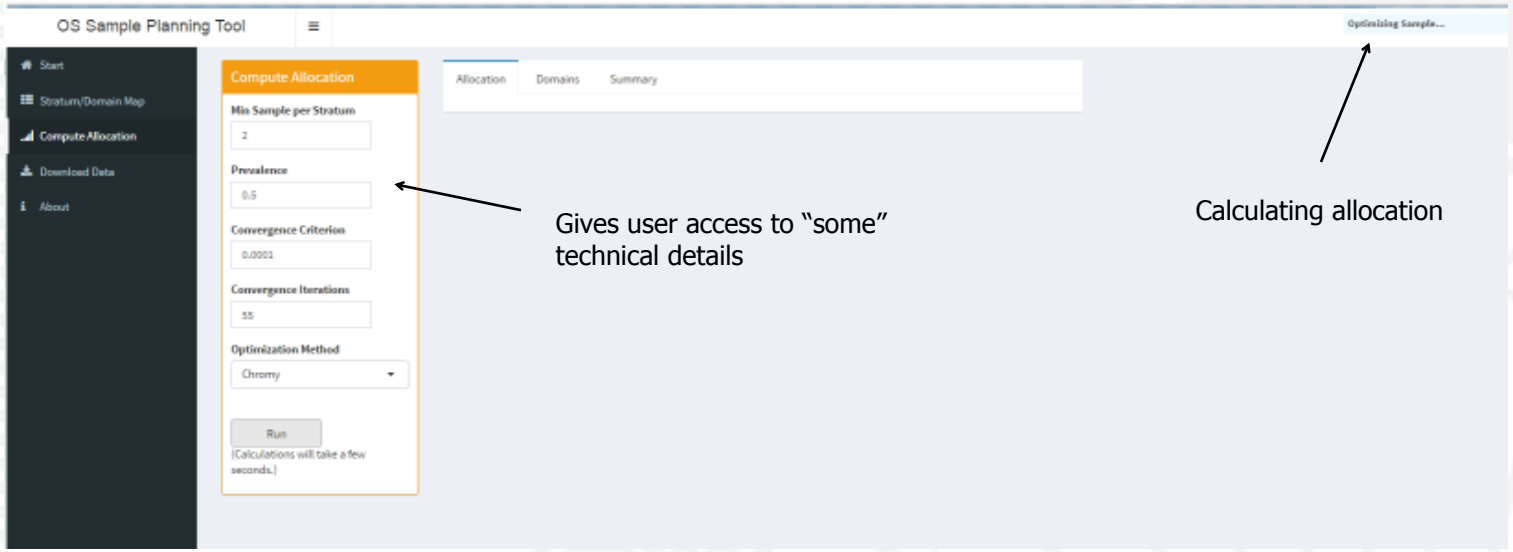
- Leverages HandsOnTable to change inputs in precision (javascript written into shiny)
  - Changing All Domains (overall) precision to 0.01

Sampling Tool Demo (contd)



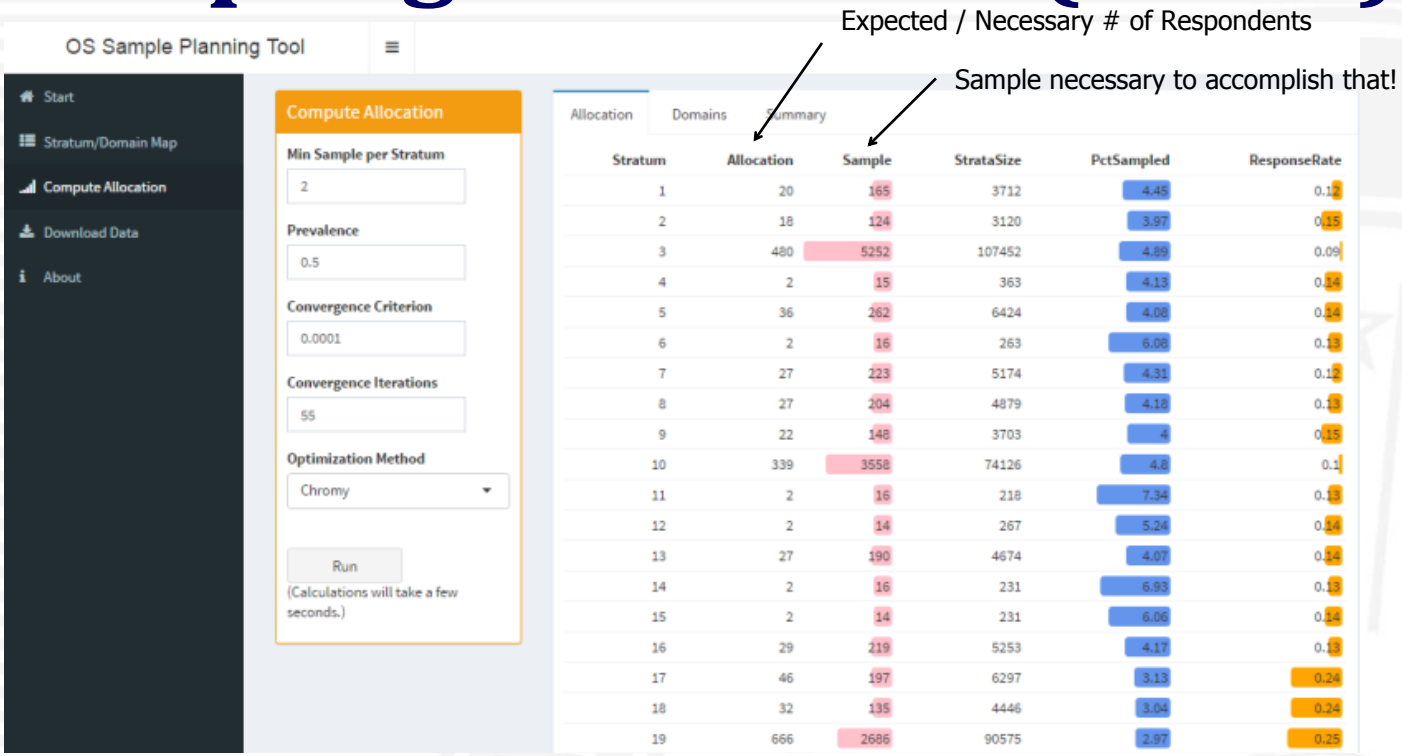
- Calculate computes:
  - Strata Sizes, Stratum/Domain Counts, Domain Sizes, Initial Lambdas
- In this example, all members are in “All Domains” thus the first few rows are equivalent to the Strata size.
  - Domain 1 Strata 1 overall size = 3712. StrDomSize = 3712.

Sampling Tool Demo (contd)



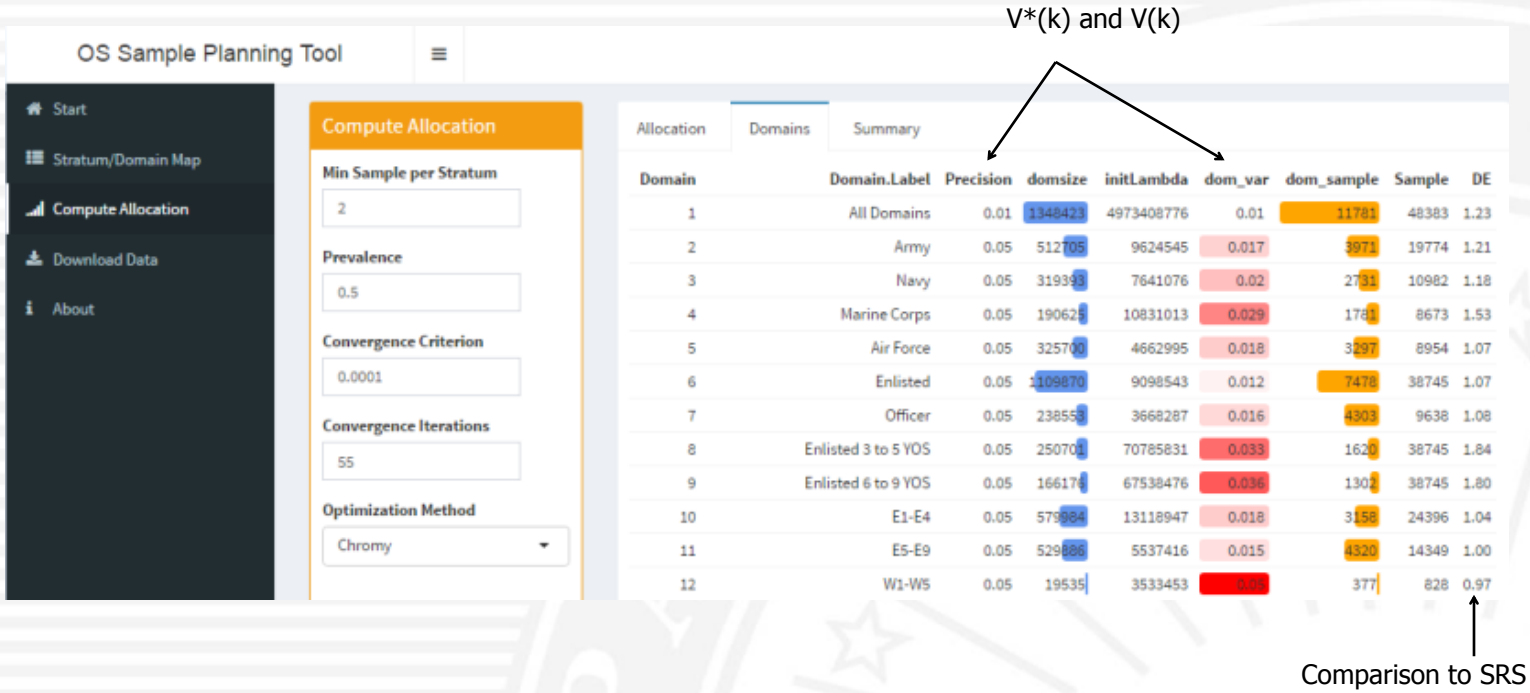
- Compute Allocation Tab
  - Access to assumptions:
    - Min Sample per stratum, Prevalence, Convergence Criterion / Max Iterations
    - Optimization Method – currently only supports "Chromy"

Sampling Tool Demo (contd)



- Key output: Stratum X Allocation
  - Other diagnostics ~ StrataSize, PctSampled, RespRate
  - Playing with “formmattable” which gives nice proportion bars

Sampling Tool Demo (contd)



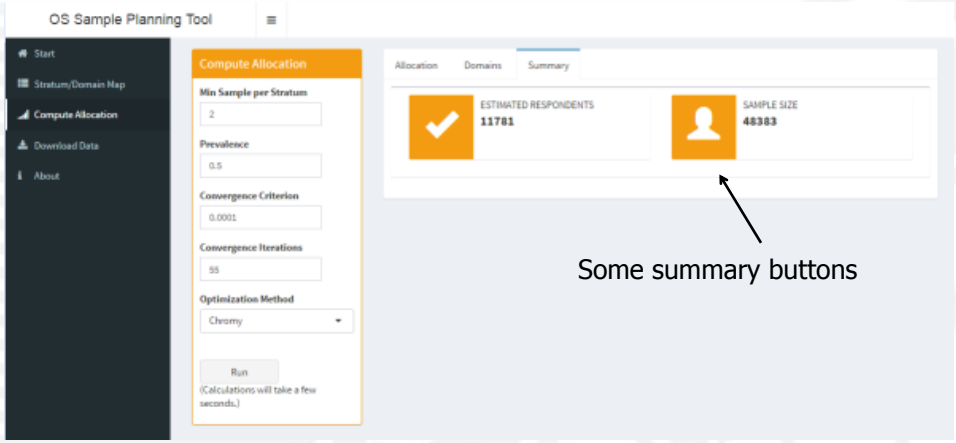
- Key output:

  Dom_var (i.e. how did our allocation do?)

  All Domain Precision V* = 0.01, dom_var = 0.01

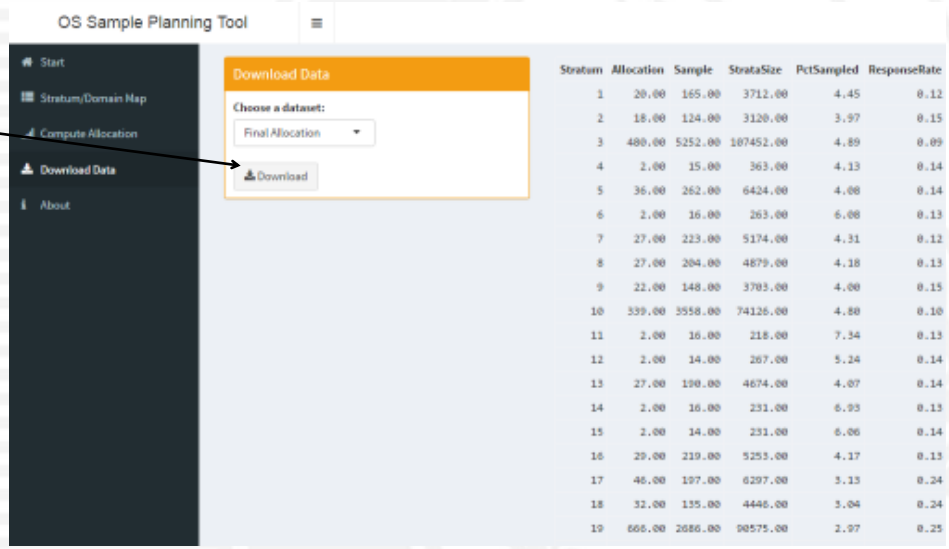
  Army Precision V* = 0.05, dom_var = 0.017

Sampling Tool Demo (contd)



Some summary buttons

Download Allocation as CSV



Stratum	Allocation	Sample	StrataSize	PctSampled	ResponseRate
1	20.00	165.00	3712.00	4.45	0.12
2	18.00	124.00	3120.00	3.97	0.15
3	480.00	5252.00	107452.00	4.89	0.09
4	2.00	15.00	363.00	4.13	0.14
5	36.00	262.00	6424.00	4.08	0.14
6	2.00	16.00	263.00	6.08	0.13
7	27.00	223.00	5174.00	4.31	0.12
8	27.00	204.00	4879.00	4.18	0.13
9	22.00	148.00	3703.00	4.00	0.15
10	339.00	3558.00	74126.00	4.80	0.10
11	2.00	16.00	218.00	7.34	0.13
12	2.00	14.00	267.00	5.24	0.14
13	27.00	190.00	4674.00	4.07	0.14
14	2.00	16.00	231.00	6.93	0.13
15	2.00	14.00	231.00	6.06	0.14
16	20.00	219.00	5253.00	4.17	0.13
17	46.00	197.00	6297.00	3.13	0.24
18	32.00	135.00	4446.00	3.04	0.24
19	666.00	2686.00	90575.00	2.97	0.25

Roadmap

- Goals:
  - Releasing Code + Working Examples
  - Generalizable
    - Can work for a forestry survey / education survey
    - Cost models only based on response rates, not $$$
  - Support other sampling designs
    - Two stage, cluster, etc.
  - Support other optimization methods
    - Currently Chromy, others in references
  - Always improvements to UX / code / etc.

References

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- R Shiny: shiny.rstudio.com
- R Consortium: r-consortium.org
- Show Me Shiny: showmeshiny.com

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- Eric Falk, Statistics Branch Team Lead, RSSC

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