Math: The gateway to Great Careers

Rob Ploutz-Snyder, Ph
Universities Space Research Associati
NASA Johnson Space Cen

What I'll Talk About Today

- Why I think that math is important for everyone in this room
- "Common Denominators" of Great Careers
- An example of how I use math at NASA

Career versus Job

- **Career** is defined by the Oxford English Dictionary as an individual's "course or progress through life (or a distinct portion of life)". It is usually considered to pertain to remunerative work (and sometimes also formal education).

- A **job** is a regular activity performed in exchange for payment, usually as one's occupation. The duration of a job may range from an hour …to a lifetime …The series of jobs a person holds in their life is their career.

Career. (2010, January 28). In *Wikipedia, The Free Encyclopedia*. Retrieved 16:36, March 3, 2010, from http://en.wikipedia.org/w/index.php?title=Career&oldid=340497790

Career versus Job

- Most of us use the two terms interchangeably
  - But when you think about it, they are different
- Age relates to which you have and which you *want* to have
- My goal is to get you thinking about what *Career* you want to develop, and about charting your path

What makes a great career?

- It depends on what matters to you, but there are some common things that many people value…

- What are some things that YOU consider important in a career?

…Things to consider…

- Salary & Benefits
- Hours
- Physical Demands
- Mental Demands
- Skill Sets Required
- Education Required
- Work Environment
- Stress
- Hiring Outlook
- Sense of Worth
- Job Security
- Flexibility
- Predictability
- Travel Requirements
- Family-Friendly
- Prestige
- Opportunities for Advancement
- Interesting!
- Co-workers

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Many, MANY things contribute to Career Satisfaction!!

What are some great careers?

- Again, it depends on what matters to you, but when asked, many people rattle off the same short list…

- What do you think is on that list??

What are some great careers?

- JobsRated.com evaluated 200 jobs in 2010, considering five “Core Criteria”
  - Environment, Income, Outlook, Stress, Physical Demands
- Each of these criteria had several components to them (ex. “income” included salary data plus growth potential)
- 200 Jobs were rated in each Core Criteria, and an overall score was created so that jobs could be ranked.

http://www.careercast.com/jobs/content/jobs-rated-methodology-2010

“Top-10” Careers?

1. **Actuary** Interprets statistics to determine probabilities of accidents, sickness, and death, and loss of property from theft and natural disasters.
2. **Software Engineer** Researches, designs, develops and maintains software systems along with hardware development for medical, scientific, and industrial purposes.
3. **Computer Systems Analyst** Plans and develops computer systems for businesses and scientific institutions
4. **Biologist** Studies the relationship of plants and animals to their environment.
5. **Historian** Analyzes and records historical information from a specific era or according to a particular area of expertise.
6. **Mathematician** Applies mathematical theories and formulas to teach or solve problems in a business, educational, or industrial climate.
7. **Paralegal Assistant** Assists attorneys in preparation of legal documents; collection of depositions and affidavits; and investigation, research and analysis of legal issues.
8. **Statistician** Tabulates, analyzes, and interprets the numeric results of experiments and surveys.
9. **Accountant** Prepares and analyzes financial reports to assist managers in business, industry and government.
10. **Dental Hygienist** Assists dentists in diagnostic and therapeutic aspects of a group or private dental practice.

See any patterns here???

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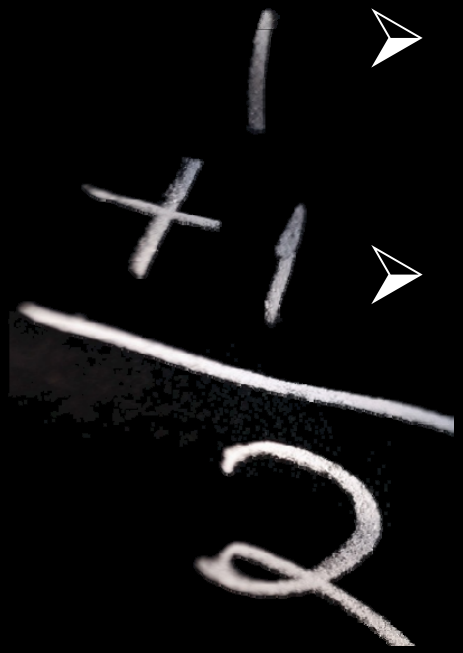
The Common Denominator:

- All of the “top ten” careers identified by JobsRated.com (Careercast.com) involve math
  - Math is part of the job
  - Knowledge of math is necessary to *get* the job



Do you agree with the list?

- This is one example of a “job survey”
- Other methods will shuffle the rankings, depending on how the survey was conducted, and how the data were analyzed (by statisticians!)

- But I would argue that the common denominators in “best” careers, regardless of how you do the math, hold true.

Math as a Gatekeeper

- Good Jobs Require…
- Good *Careers* Require…
- *Great Careers* Require…

- Most experts agree that education is a critical factor

Setting your Sights High!

- College is a no-brainer
- Graduate School is something to consider too
- What does it take to get into an excellent College or University? Graduate Program?

College Entrance Requirements

- Admissions Offices use many criteria, but most emphasize:
  - Your High School Performance
    - Cumulative GPA
    - GPA in specific courses
    - Other factors that separate you from “the pack”
  - Standardized Test Scores
    - ACT
      - Math, English, Reading, Science, Optional Writing Test, Composite
    - SAT
      - Math
      - Writing
      - Critical Reading

Graduate School?

- Admissions Offices & Disciplines for Graduate School mimic Undergrad:
  - Your Performance in College/University
    - Cumulative Undergraduate GPA
    - GPA in specific courses
    - Other factors
  - Standardized Test Scores
    - GRE
      - Quantitative Reasoning
      - Verbal Reasoning
      - Analytical Writing
    - MCAT or OTHER Discipline-Specific Tests
      - …have a math component!

What most applicants want?

- Opportunity
  - to highlight our strengths
  - to address our weaknesses
  - to learn what it takes to succeed

- …We need to get our foot in the door

What are the “gatekeepers?”

- Standardized Test Scores
  - SAT, ACT, GRE, etc.
- Cumulative GPA

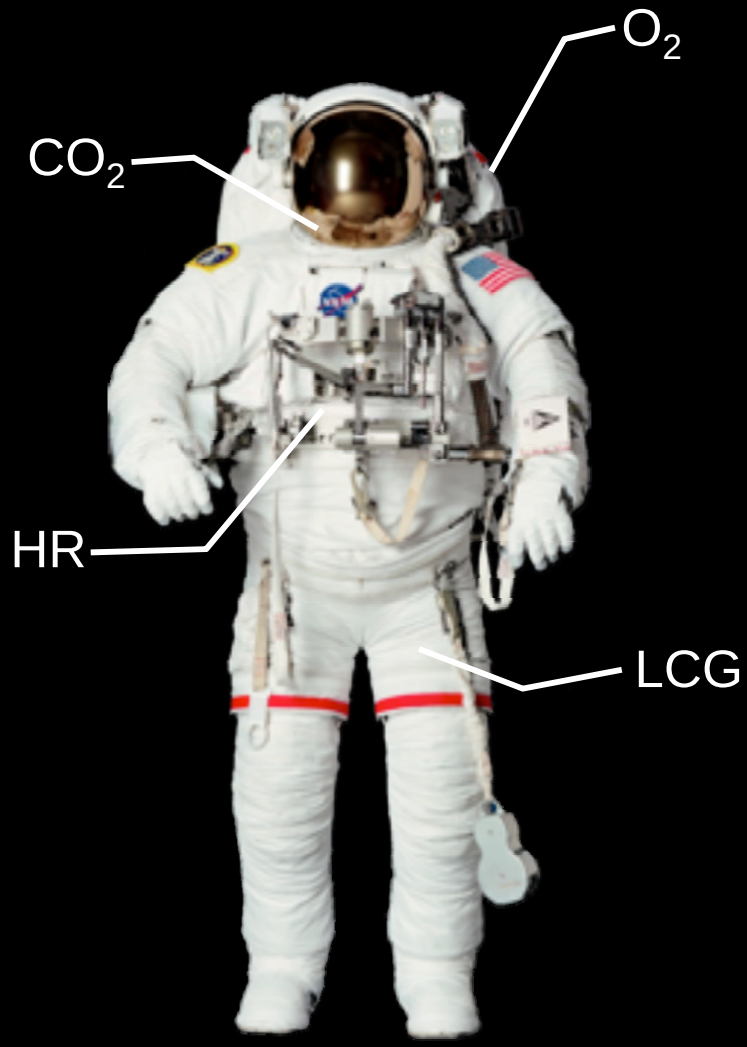
Why is Math so Important as an Entrance Requirement?

- People with math skills typically learn *other* academic and career-related disciplines, so they are a good risk for colleges/universities
- People who have solid math skills are thought to be “smart people,” and thus are welcomed into college programs, training opportunities, and great careers
- Math is part of most careers at some level

Recent Example of NASA work

The Challenge?

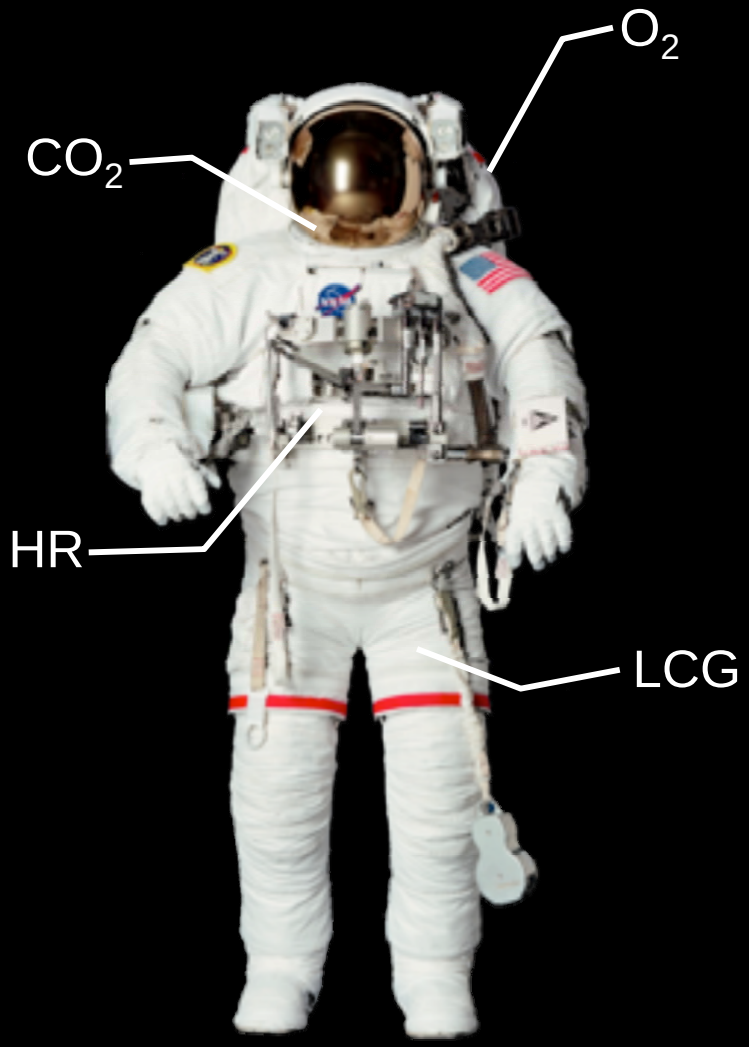
- Need to be able to accurately predict when an astronaut will run out of “consumables” during Extra Vehicular Activities
- There are several ways to estimate this, but sometimes the estimates don’t match
- How best to combine predictions from multiple methods of estimating??



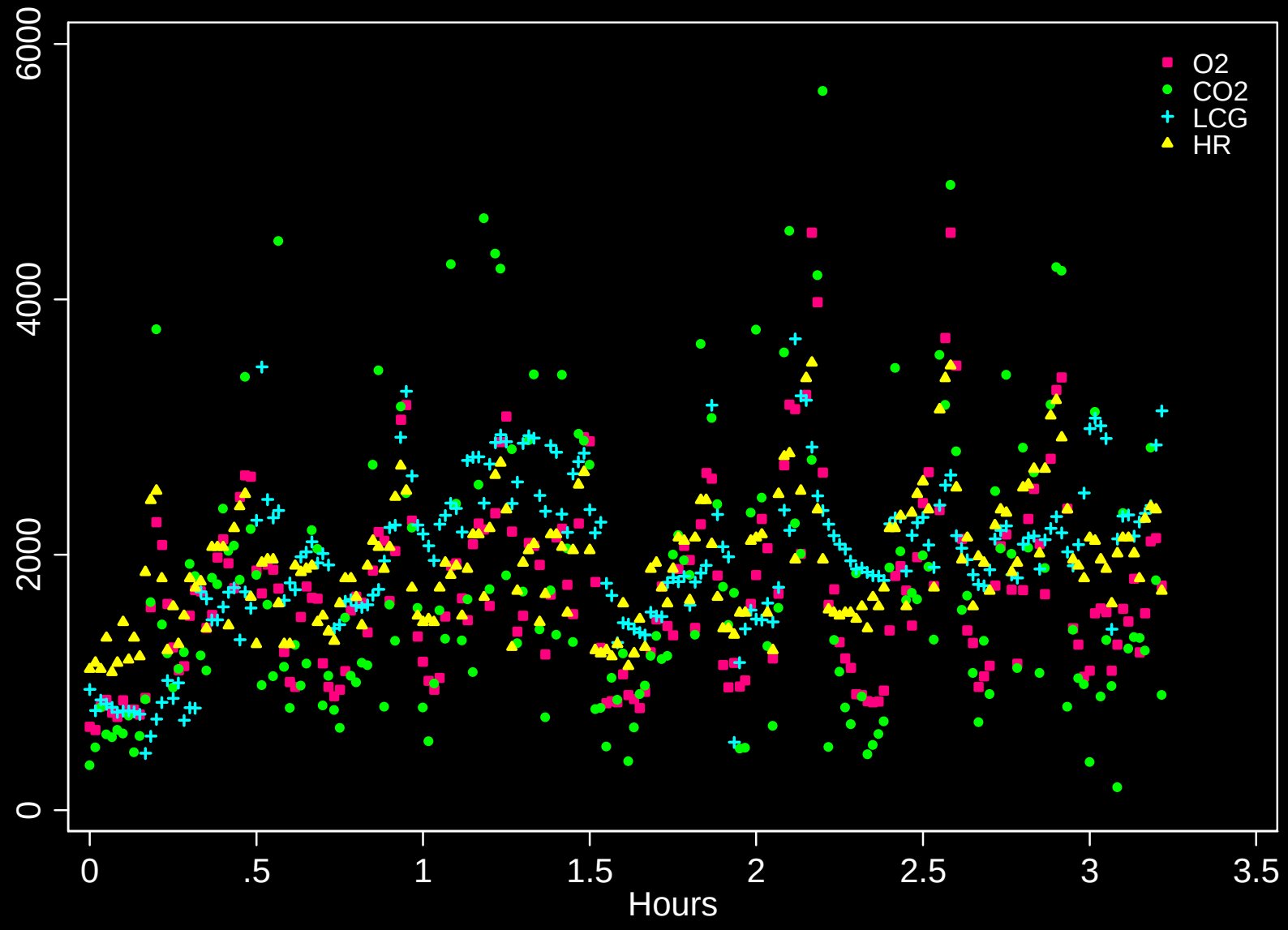
Recent Example of NASA work

Oh, and one more thing…

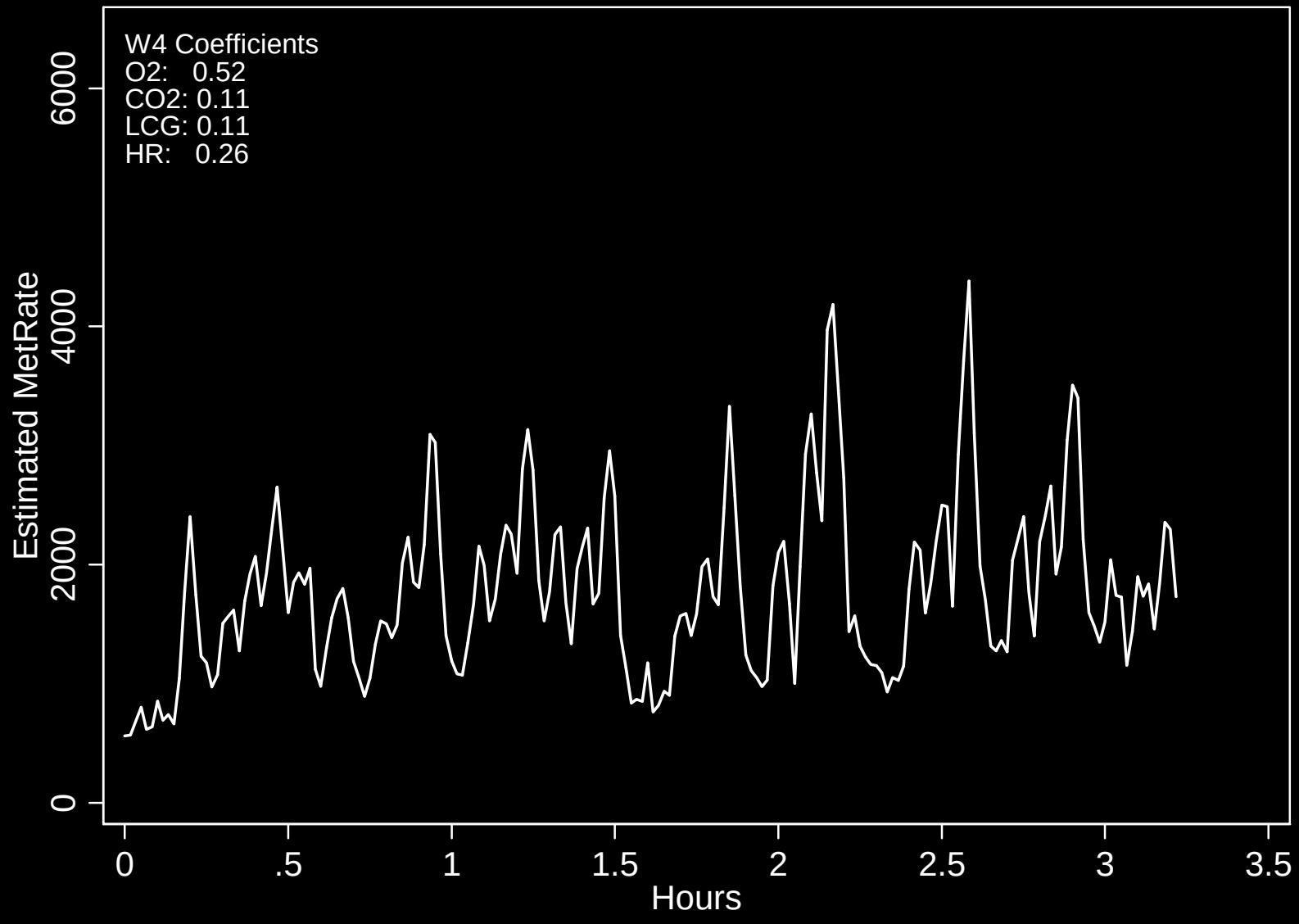
- Find a method that works even when things go wrong!
  - Crazy readings from a sensor
  - Flaky sensor that goes in/out
  - Completely broken sensor
  - Combinations of the above
  - Other stuff that we'll think of too!



What the data looks like?



Our “Best Estimate”



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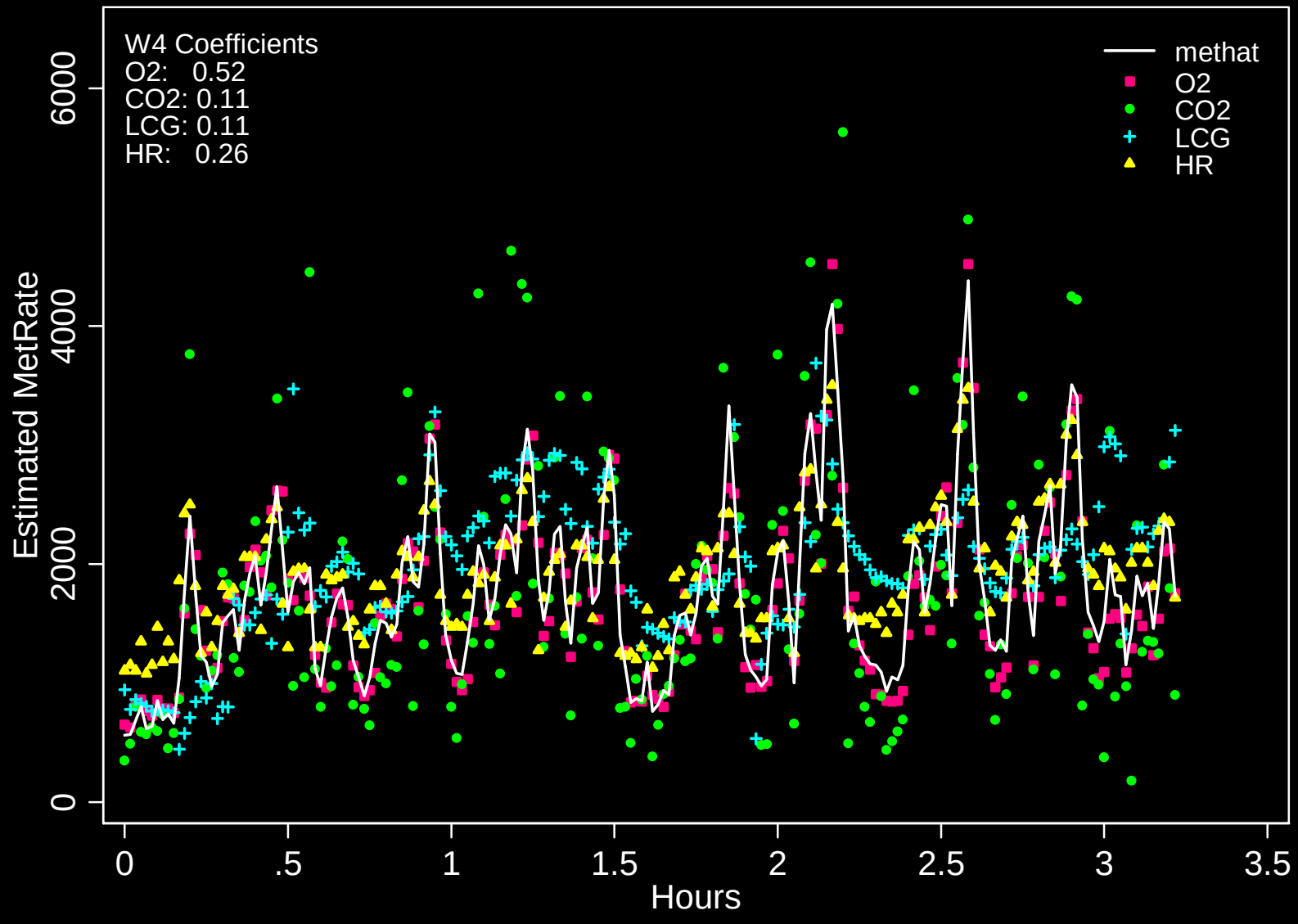
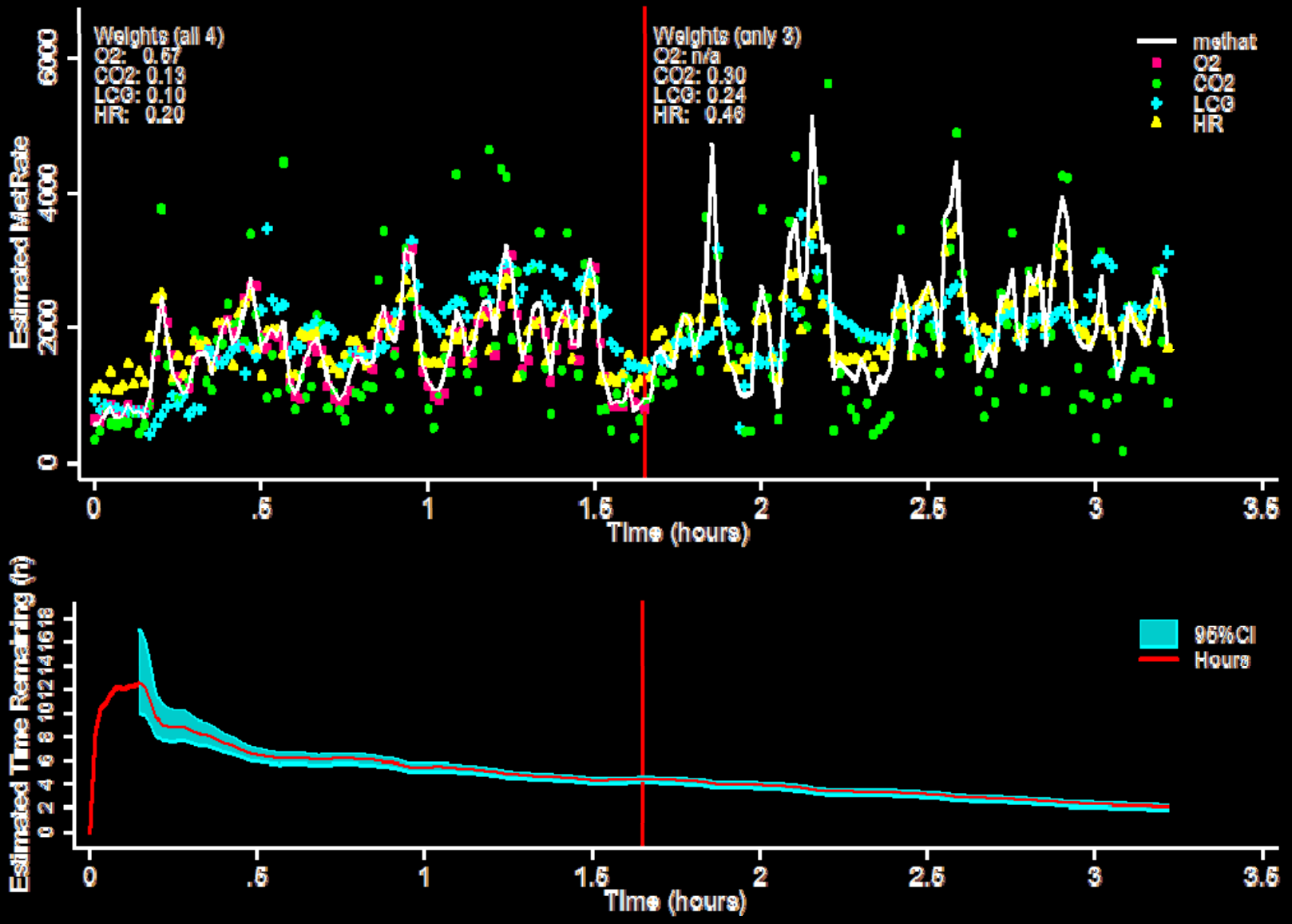


What if a sensor fails?



How did we do it??

Summary of Met Rate (μ) Estimation Process

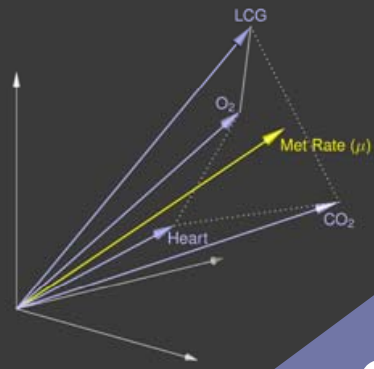
Step 1. Preliminary estimation of μ. Apply principal-axis analysis to x_1, x_2, and x_3 with one retained factor assumed to be proportional to μ. Use (2)-(4) to get preliminary estimate $\mu^{(0)}$.

Step 2. Preliminary calibration of heart rate (HR). Assume for some α_0 and α_1, that $\alpha_0+\alpha_1(HR)$ is also an unbiased estimate of μ. Regress $\mu^{(0)}$ on HR to get preliminary calibration $x_4^{(0)} = \hat{\alpha}_0 + \hat{\alpha}_1(HR)$.

Step 3. Intermediate estimation of μ. Repeat factor analysis with 4 variables x_1, x_2, x_3, and $x_4^{(0)}$. Again use (2)-(4) to get new estimate $\mu^{(1)}$ of μ.

Step 4. Final calibration of heart rate. Regress $\mu^{(1)}$ on HR to get final calibration x_4 of HR.

Step 5. Final estimation of μ. Repeat factor analysis with 4 variables x_1, x_2, x_3, and x_4 and use (2)-(4) to obtain final estimate $\hat{\mu}$.



Estimation of μ

$\hat{\mathbf{f}} = \tilde{\mathbf{X}}\mathbf{R}^{-1}\boldsymbol{\Lambda}$

$= (\mu\mathbf{J}$

equa

$\boldsymbol{\Lambda}$

$/\mu - (\mathbf{MD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda})\mathbf{j}$

$\mathbf{j}$

$\mathbf{f} + \hat{\mu}\mathbf{j}$ (3)

$\hat{\alpha} = \mathbf{JD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda}; \quad \hat{\mu} = \frac{1}{\hat{\alpha}}\mathbf{MD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda}$ (4)

Met Rate Factor Model

Principal factor (f)

$\mu = n \times 1$ vector of true met rate values

$\mathbf{f}$ = principal factor $= \alpha(\mu - \bar{\mu}\mathbf{j})$

$\bar{\mu} = (1/n)\mu'\mathbf{j}$; $\mathbf{j} = (1, 1, \ldots, 1)'$

Observed estimators of met rate (asumed unbiased)

$$\underset{n\times 1}{\mathbf{x}_i} = \underset{n\times 1}{\boldsymbol{\mu}} + \underset{n\times 1}{\mathbf{e}_i} \quad (i = 1 \ldots k)$$

$$\underset{n\times k}{\mathbf{X}} = (\mathbf{x}_1 | \ldots | \mathbf{x}_k) = \underset{n\times 1}{\boldsymbol{\mu}}\,\underset{1\times k}{\mathbf{J}} + \underset{n\times 1}{\mathbf{e}} \qquad (1)$$

Factor estimation

$$\hat{\mathbf{f}} = \tilde{\mathbf{X}}\mathbf{R}^{-1}\boldsymbol{\Lambda} \qquad (2)$$

$$\tilde{\mathbf{X}} = (\mathbf{X} - \mathbf{jM})\mathbf{D}^{-1}$$

where
- $\boldsymbol{\Lambda}$ = $k \times 1$ factor loading matrix
- $\mathbf{M} = (M_1, \ldots, M_k)'$ (sample means)
- $\mathbf{D} = \text{diag}(s_1, \ldots, s_k)'$ (sample SDs)
- $\mathbf{R}$ = $k \times k$ correlation matrix of X

Weight vector ($\mathbf{b}$)

$$\begin{aligned}\hat{\boldsymbol{\mu}} &= \frac{1}{\hat{\alpha}}\hat{\mathbf{f}} + \hat{\mu}\mathbf{j} \\ &= \frac{1}{\hat{\alpha}}\tilde{\mathbf{X}}\mathbf{R}^{-1}\boldsymbol{\Lambda} + \hat{\mu}\mathbf{j} \\ &= \frac{1}{\hat{\alpha}}(\mathbf{X} - \mathbf{jM})\mathbf{D}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda} + \hat{\mu}\mathbf{j} \\ &= \frac{1}{\hat{\alpha}}\mathbf{XD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda} - \frac{1}{\hat{\alpha}}\mathbf{j}(\mathbf{MD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda}) + \hat{\mu}\mathbf{j} \\ &= \frac{1}{\hat{\alpha}}\mathbf{XD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda} \\ &= \underset{n\times k}{\mathbf{X}}\ \underset{k\times 1}{\mathbf{b}}\end{aligned}$$

where $\mathbf{b} = \frac{1}{\hat{\alpha}}\mathbf{D}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda}$

(Note: $\mathbf{Jb} = \frac{1}{\hat{\alpha}}\mathbf{JD}^{-1}\mathbf{R}^{-1}\boldsymbol{\Lambda} = 1$)

Estimate of BTU's used ($\hat{B}$)

$$\begin{aligned}\hat{B} &= \hat{\boldsymbol{\mu}}'\mathbf{j}\Delta t \\ &= \mathbf{b}'\mathbf{X}'\mathbf{j}\Delta t \\ &= \mathbf{b}'(\mathbf{J}'\boldsymbol{\mu}' + \mathbf{e}')\mathbf{j}\Delta t \\ &= \mathbf{b}'\mathbf{J}'\boldsymbol{\mu}'\mathbf{j}\Delta t + \mathbf{b}'\mathbf{e}'\mathbf{j}\Delta t \\ &= \boldsymbol{\mu}'\mathbf{j}\Delta t + \mathbf{b}'\mathbf{e}'\mathbf{j}\Delta t \text{ (since } \mathbf{b}'\mathbf{J}' = \mathbf{Jb} = 1)\end{aligned}$$

Let $V(\mathbf{e}'\mathbf{j}) = \underset{k\times k}{\boldsymbol{\Sigma}}$ and assume $\mathbf{b}, \mathbf{e}$ independent.

Then $V(\hat{B}) = (\Delta t)^2 E_0(\mathbf{b}'\boldsymbol{\Sigma}\mathbf{b})$, estimated by $(\Delta t)^2\mathbf{b}'\boldsymbol{\Sigma}\mathbf{b}$.

Estimation of Σ

Step 1. Assume the components of each $\mathbf{e}_i$ follow a second-order autoregressive model:

Step 2. $e_{ij} = \rho_{i2}e_{i,j-2} + \rho_{i1}e_{i,j-1} + \epsilon_{ij}; \quad \epsilon_{ij} \overset{i.i.d.}{\sim} (0, \sigma^2)$.

Step 3. Perform AR(2) regression of $\mathbf{x}_i$ on $\hat{\boldsymbol{\mu}}$ to obtain estimates of σ^2, ρ_{i1}, and ρ_{i2} $(i = 1, \ldots, k)$

Step 4. Calculate $\Sigma_{ii} = V(\mathbf{e}'\mathbf{j}) = \frac{n\sigma^2}{1 - \rho_{i1} - \rho_{i2}}$.

Step 5. Assume uncorrelated $\mathbf{e}_i$: $\boldsymbol{\Sigma} = \text{diag}(\Sigma_{ii})$

Estimation of Allowable Time Remaining in EVA

Write $\hat{B}(T)$ = $\hat{B}$ after T hours of EVA.

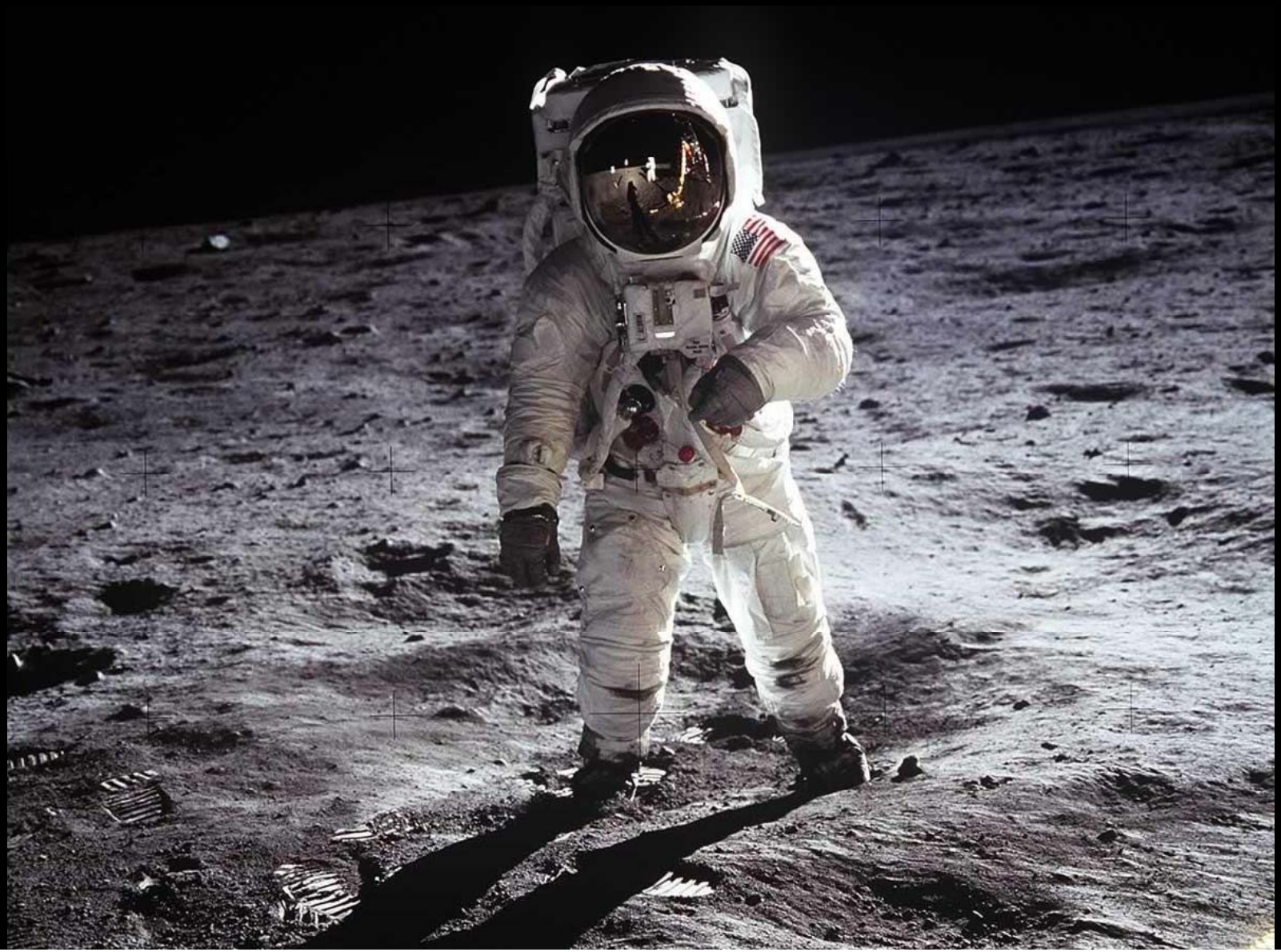
Assume spacesuit life support system can accommodate a maximum total energy expenditure of B_{max} (BTU).

Then the time remaining T_r is estimated by $\hat{T}_r = B_{max}T/\hat{B}(T) - T$.

Use $\Delta t(\mathbf{b}'\hat{\boldsymbol{\Sigma}}\mathbf{b})^{1/2}$ as SE of $\hat{B}(T)$ to get confidence limits for T_r.

With a little math!!

Problem Solved??



Final Remarks…

Take-Home Lesson #1 ?

- Math Matters
- Math can be a career in and of itself
- Applied math leads to many careers
- These careers tend to be highly praised, with attributes that most people value

For the Math Lovers…

- Good news for us! Actuary Accountant Statistician Researcher Programmer Mathematician Engineer
- Jobs requiring what we like to think about and do are “out there!”
- All that “math stuff” that we learn in school really has a purpose in life and work!
- We can get *paid* to do stuff that we love to do anyway!!
- And we can make a difference in the world too.

Take-Home Lesson #2 ?

- Math Matters
- Math is a “gatekeeper” to great careers not typically thought of as “in the math field” because it is a key component to the entrance exams required for College, University, and Post-Graduate education

For everyone else??

- There are many great careers that don't involve (as much) math as part of daily "work-life"

Historian
Dental Hygienist
Paralegal Assistant
Philosopher
Technical Writer
Web Developers
Pharmacist
…many others

- With equal benefits to self and society

- Nevertheless, many of the jobs that people rate highly require knowledge of math
  - If for no other purpose, math serves as a "gate keeper" to great careers

Where will your career take you?

Go down deep enough into anything and you will find mathematics.

~Dean Schlicter