Math: The gateway to Great Careers

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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???

1. Actuary Interprets statistics to determine probabilities of accidents, sickness, and death, and loss of property from theft and natural disasters.
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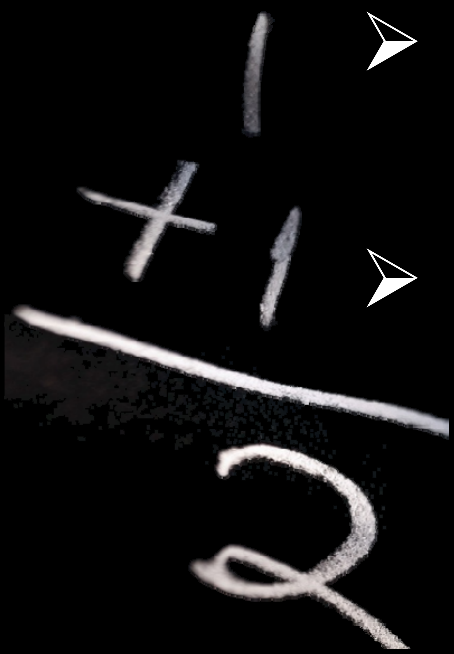
The Common Denominator:

- 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

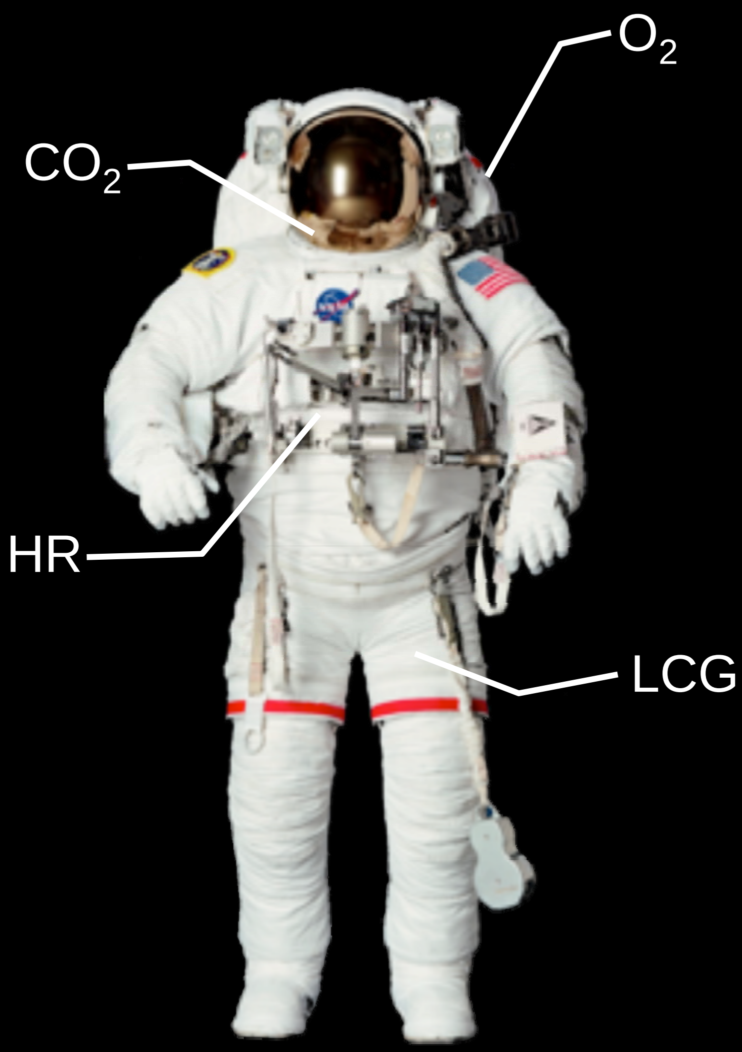
Why is Math so Important as an Entrance Requirement?

- 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?

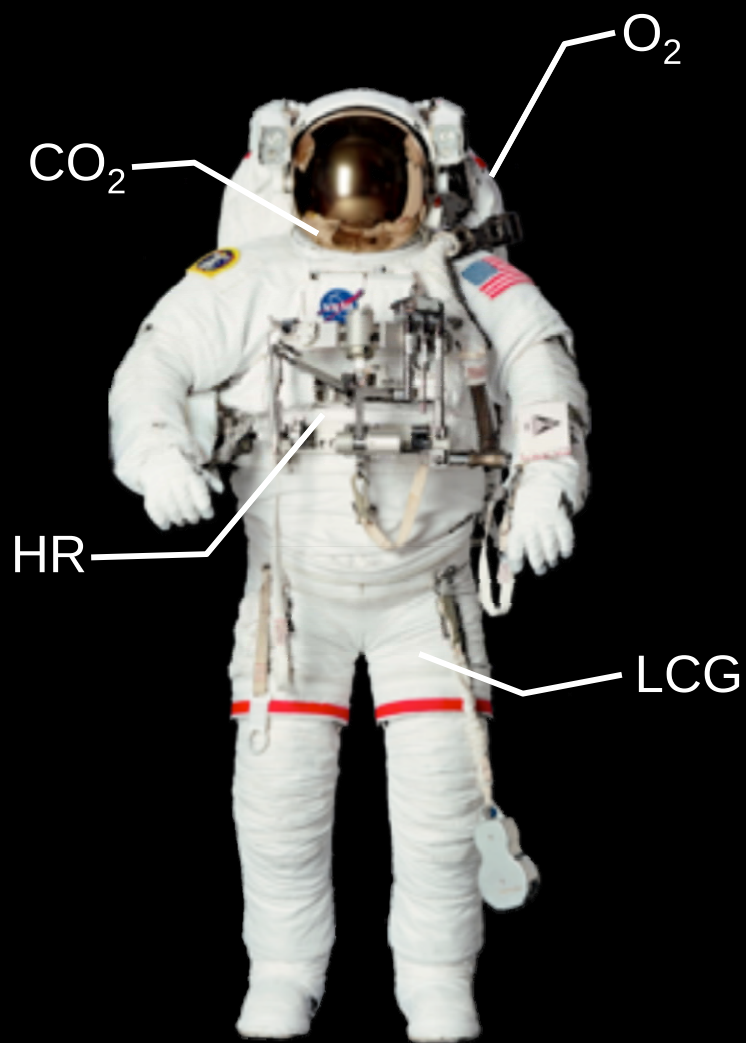
- Need to be able to accurately predict when an astronaut will run out of “consumables” during Extra Vehicular Activities
- There are several ways to estimate this, but sometimes the estimates don’t match
- How best to combine predictions from multiple methods of estimating??



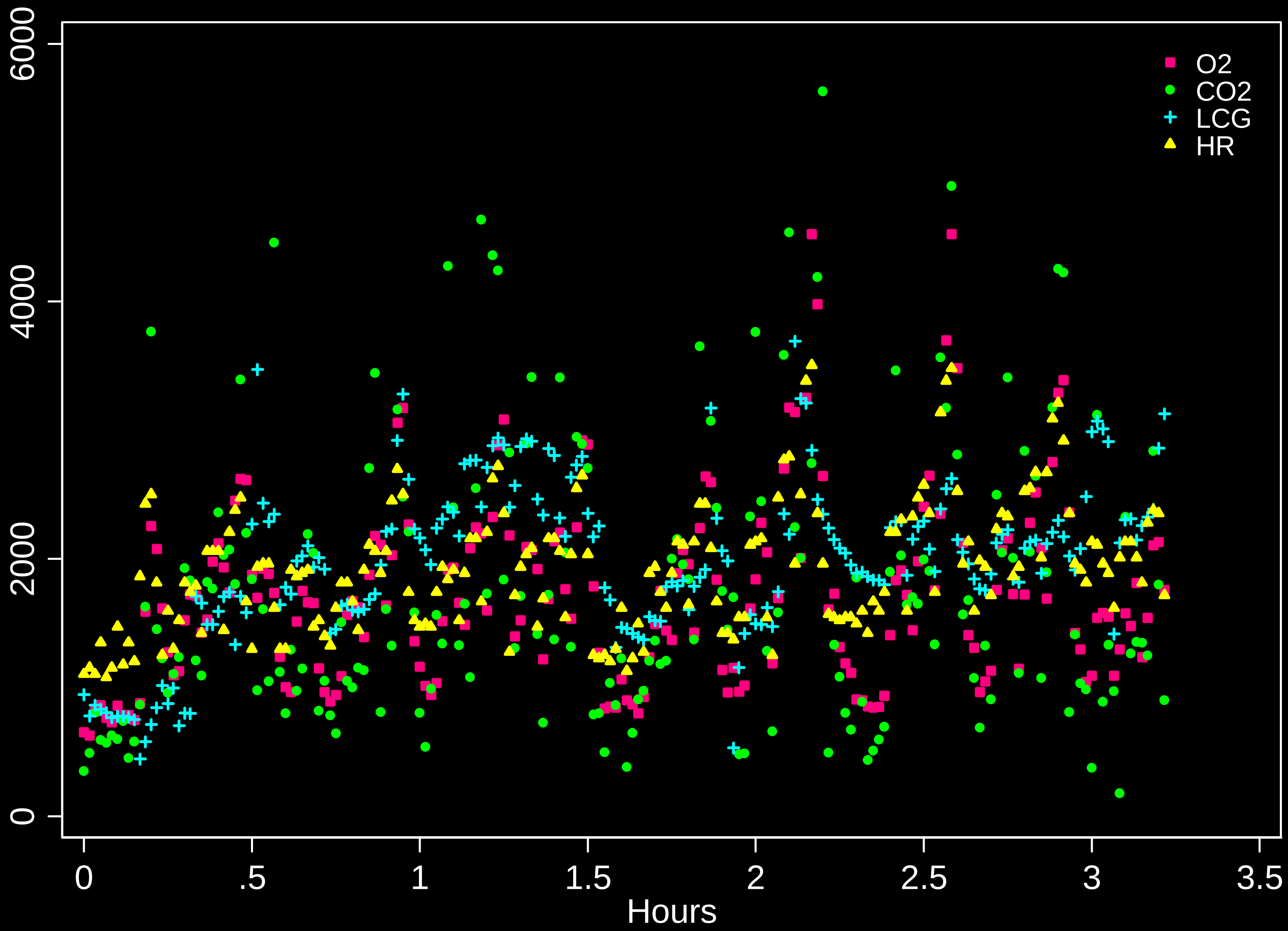
Recent Example of NASA work

Oh, and one more thing…

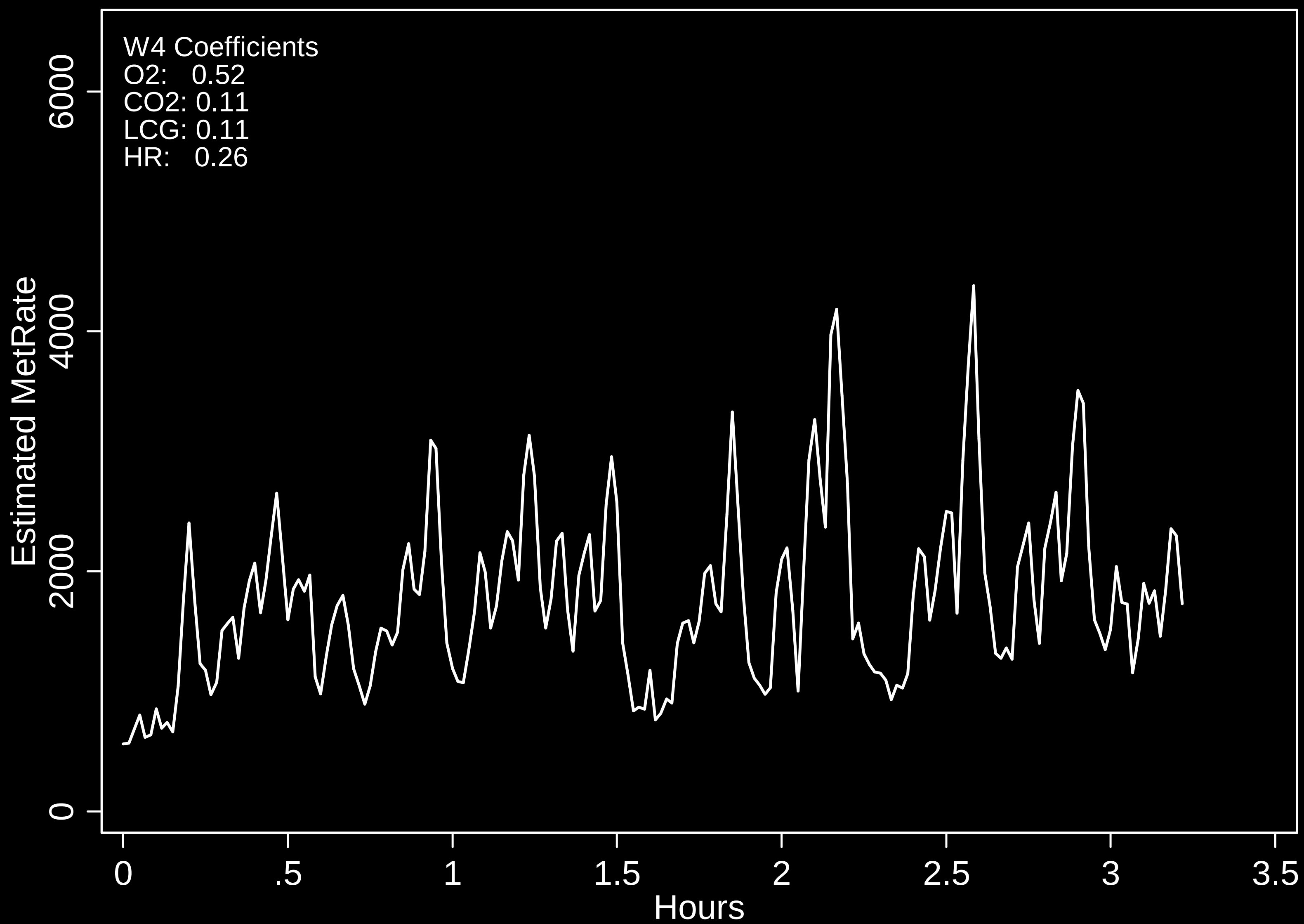
- Find a method that works even when things go wrong!
  - Crazy readings from a sensor
  - Flaky sensor that goes in/out
  - Completely broken sensor
  - Combinations of the above
  - Other stuff that we'll think of too!



What the data looks like?



Our "Best Estimate"



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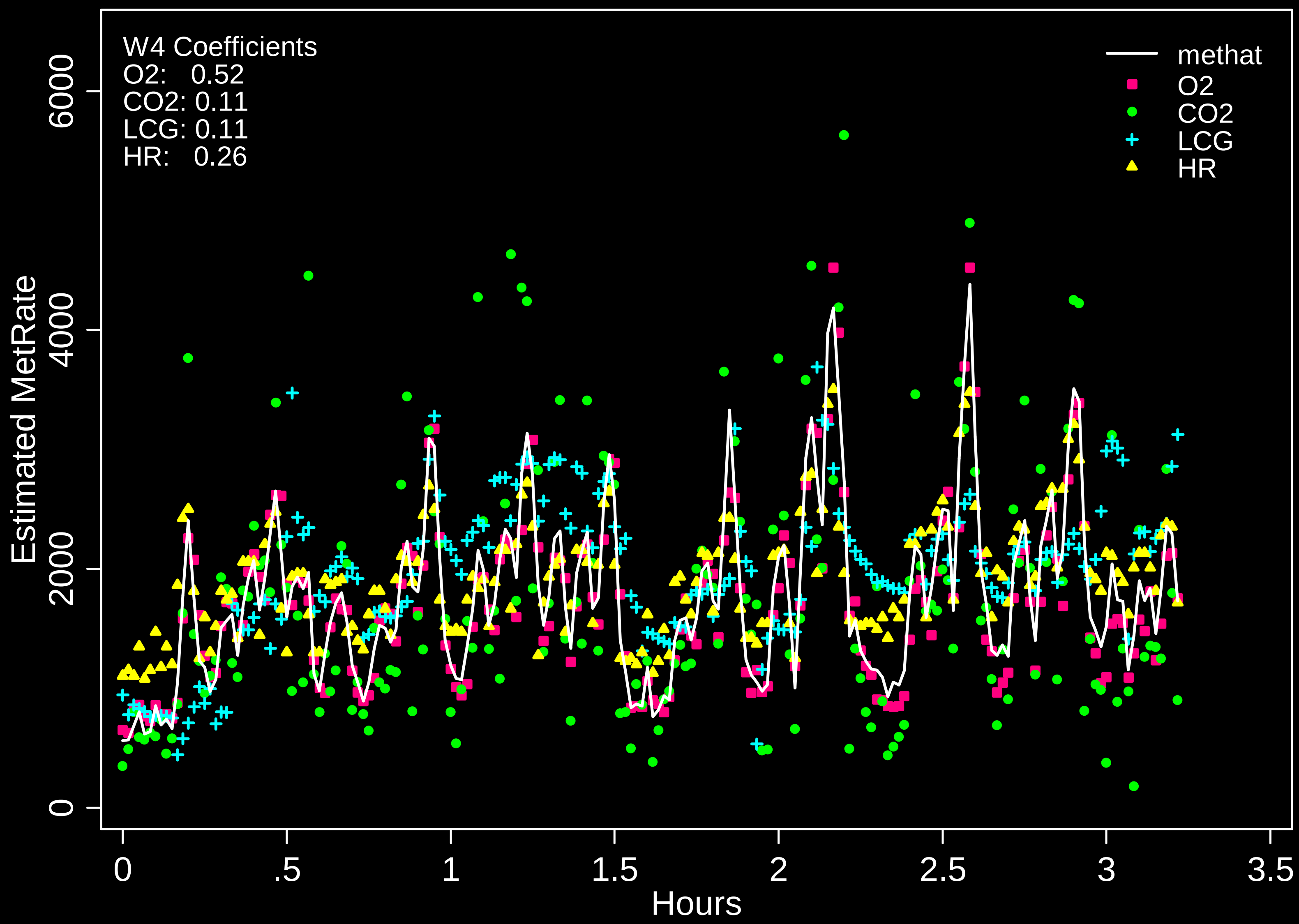
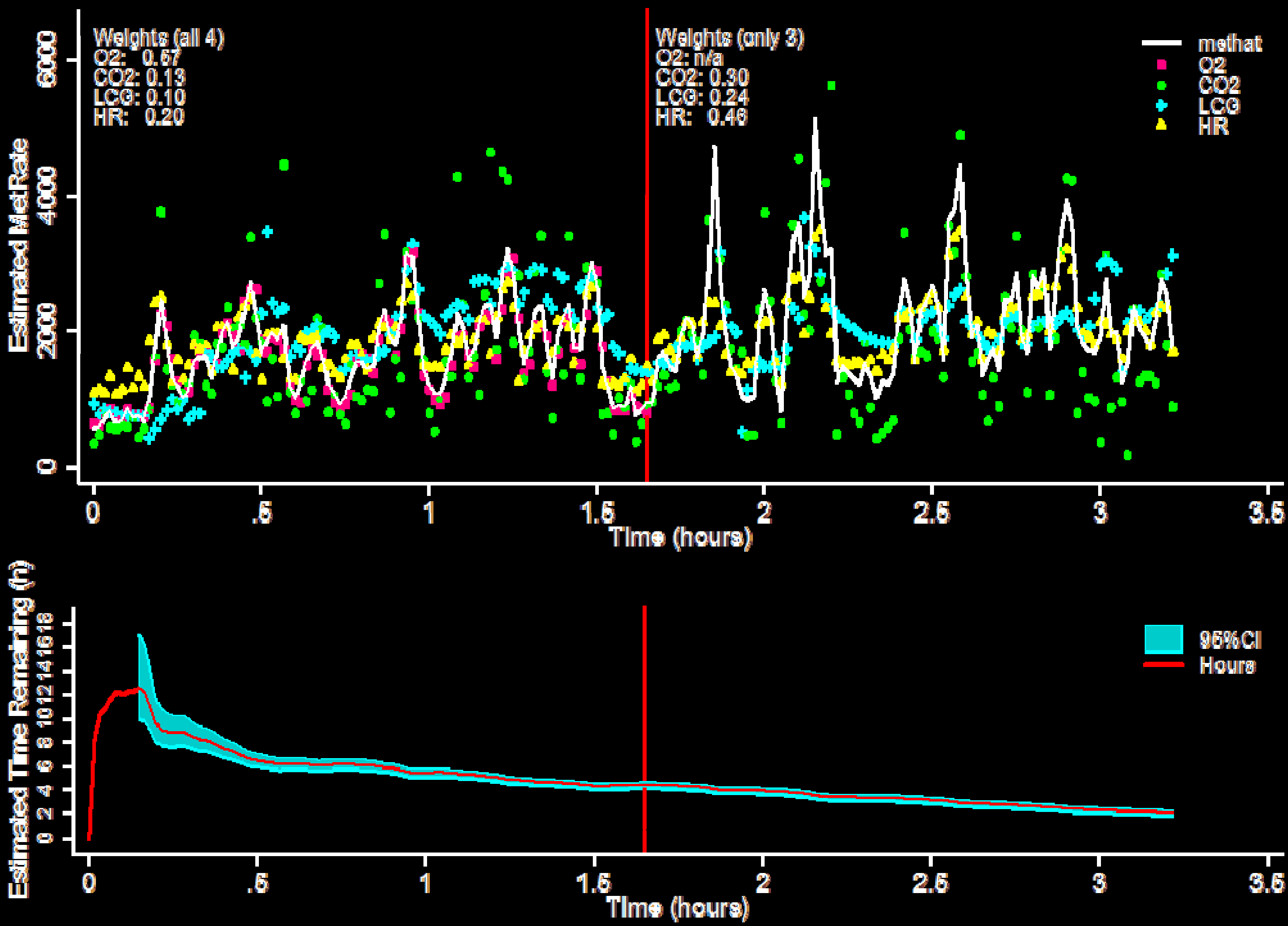


What if a sensor fails?



How did we do it??

Summary of Met Rate (μ) Estimation Process

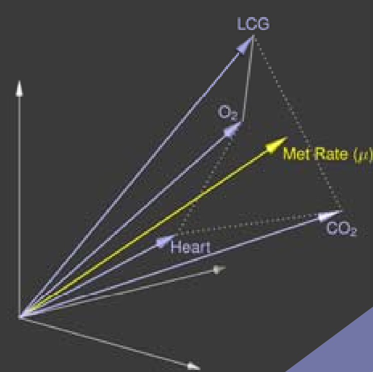
Step 1. Preliminary estimation of μ. Apply principal-axis analysis to $\mathbf{x}_1, \mathbf{x}_2$, and $\mathbf{x}_3$ with one retained factor assumed to be proportional to μ. Use (2)-(4) to get preliminary estimate $\mu^{(0)}$.

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 $\mathbf{x}_4^{(0)} = \hat{\alpha}_0 + \hat{\alpha}_1(HR)$.

Step 3. Intermediate estimation of μ. Repeat factor analysis with 4 variables $\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3$, and $\mathbf{x}_4^{(0)}$. 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 $\mathbf{x}_4$ of HR.

Step 5. Final estimation of μ. Repeat factor analysis with 4 variables $\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3$, and $\mathbf{x}_4$ and use (2)-(4) to obtain final estimate $\hat{\mu}$.



Estimation of μ

$$\hat{\mathbf{f}} = \tilde{\mathbf{X}}\mathbf{R}^{-1}\Lambda$$
$$= (\mu\mathbf{J} \ldots$$

equa…

$$\ldots\Lambda$$
$$\ldots\mu - (\mathbf{M}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda)\mathbf{j}$$
$$\ldots\mathbf{j}$$
$$\ldots\frac{1}{\alpha}\mathbf{f} + \bar{\mu}\mathbf{j} \quad (3)$$

$$\hat{\alpha} = \mathbf{J}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda; \quad \hat{\bar{\mu}} = \frac{1}{\hat{\alpha}}\mathbf{M}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda \quad (4)$$

With a little math!!

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

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

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

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

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 $\hat{\mu}$ to obtain estimates of σ^2, ρ_{i1}, and $\rho_{i2} \quad (i = 1, \ldots, k)$

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

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

Met Rate Factor Model

Principal factor (f)

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

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

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

Observed estimators of met rate (asumed unbiased)

$$\underset{n\times1}{\mathbf{x}_i} = \underset{n\times1}{\mu} + \underset{n\times1}{\mathbf{e}_i} \quad (i = 1 \ldots k)$$
$$\underset{n\times k}{\mathbf{X}} = (\mathbf{x}_1|\ldots|\mathbf{x}_k) = \underset{n\times1}{\mu}\;\underset{1\times k}{\mathbf{J}} + \underset{n\times1}{\mathbf{e}} \quad (1)$$

Factor estimation

$$\hat{\mathbf{f}} = \tilde{\mathbf{X}}\mathbf{R}^{-1}\Lambda \quad (2)$$
$$\tilde{\mathbf{X}} = (\mathbf{X} - \mathbf{j}\mathbf{M})\mathbf{D}^{-1}$$

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

Weight vector (b)

$$\begin{aligned}\hat{\mu} &= \frac{1}{\hat{\alpha}}\hat{\mathbf{f}} + \hat{\bar{\mu}}\mathbf{j}\\ &= \frac{1}{\hat{\alpha}}\tilde{\mathbf{X}}\mathbf{R}^{-1}\Lambda + \hat{\bar{\mu}}\mathbf{j}\\ &= \frac{1}{\hat{\alpha}}(\mathbf{X} - \mathbf{j}\mathbf{M})\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda + \hat{\bar{\mu}}\mathbf{j}\\ &= \frac{1}{\hat{\alpha}}\mathbf{X}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda - \frac{1}{\hat{\alpha}}\mathbf{j}(\mathbf{M}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda) + \hat{\bar{\mu}}\mathbf{j}\\ &= \frac{1}{\hat{\alpha}}\mathbf{X}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda\\ &= \underset{n\times k}{\mathbf{X}}\;\underset{k\times1}{\mathbf{b}}\end{aligned}$$

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

(Note: $\mathbf{J}\mathbf{b} = \frac{1}{\hat{\alpha}}\mathbf{J}\mathbf{D}^{-1}\mathbf{R}^{-1}\Lambda = 1$)

Estimation of Allowable Time Remaining in EVA

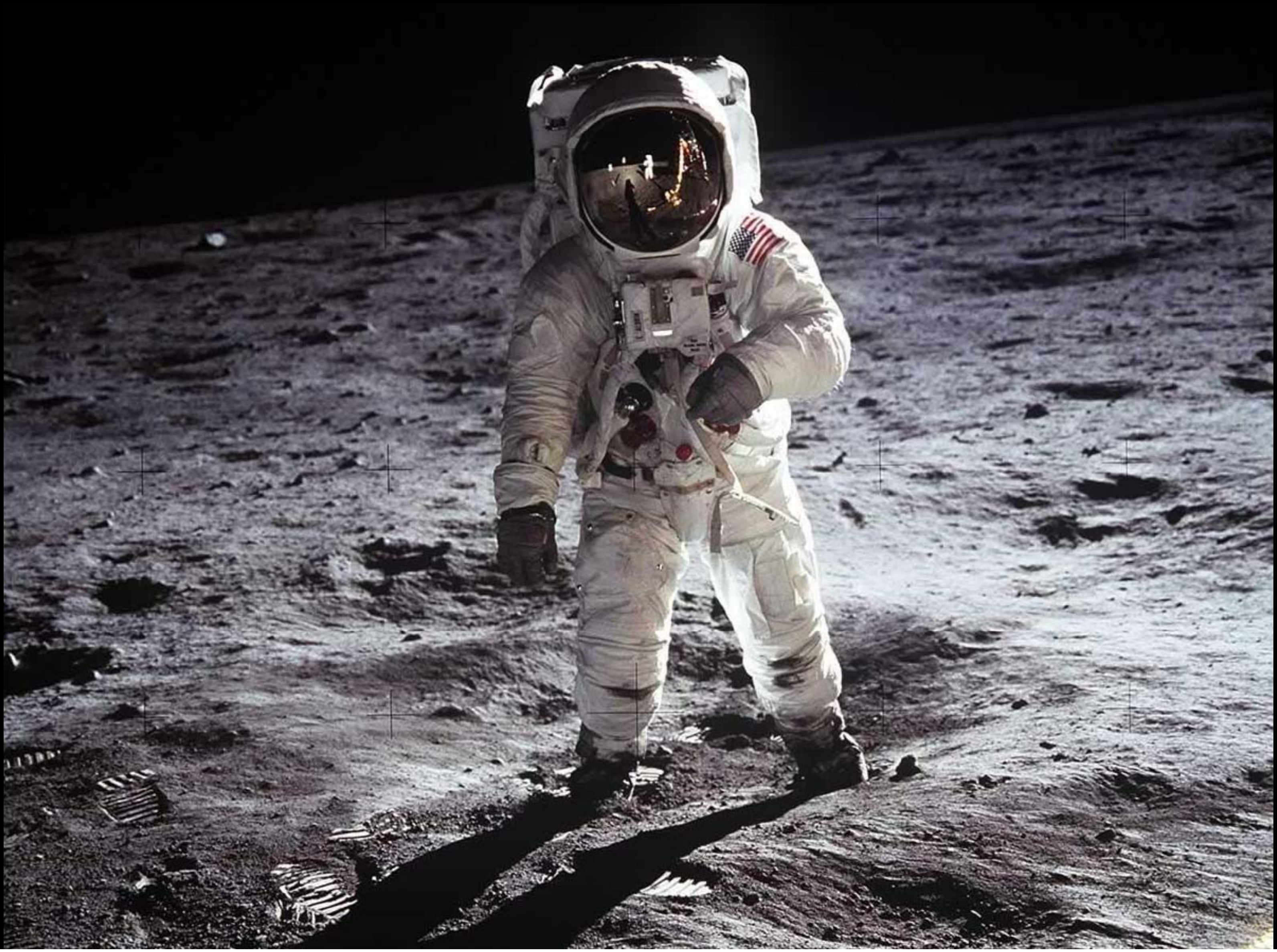
Write $\hat{B}(T)$ = $\hat{B}$ after T hours of EVA.

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

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