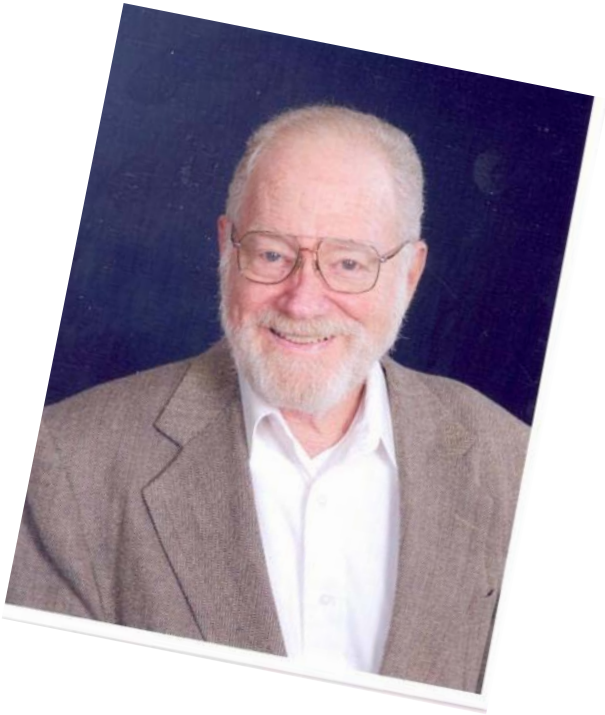
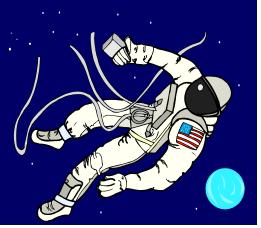
Lessons Learned from Fifty Years of Observing Hardware and Human Behavior

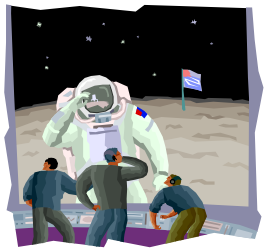
Joe McMann

August, 2011

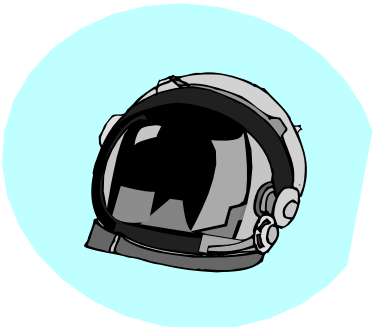



SPACE MAN
N.A.S.A

Joe McMann Bio



- Born June 28, 1937 in Oklahoma City, Oklahoma
- Graduated in 1959 with BS in Chemical Engineering from Univ. of Notre Dame
- 1959-1961: Application Engineer for Liquid Carbonic, Chicago, IL
- 1961-1997: Project Engineer, and manager with NASA JSC – associated with environmental control systems and space suit systems-acted as test subject, real-time support engineer
- 1997-2002: Technical Specialist for Hamilton-Sundstrand – associated with space suit failure resolution - development of urine measurement system – teaching failure recovery planning – mentoring
- 2002 – present: Consultant to NASA and industry – co-authored "US Spacesuits" with Ken Thomas of Hamilton Sundstrand – participant in JSC Spacesuit System Knowledge Capture initiative



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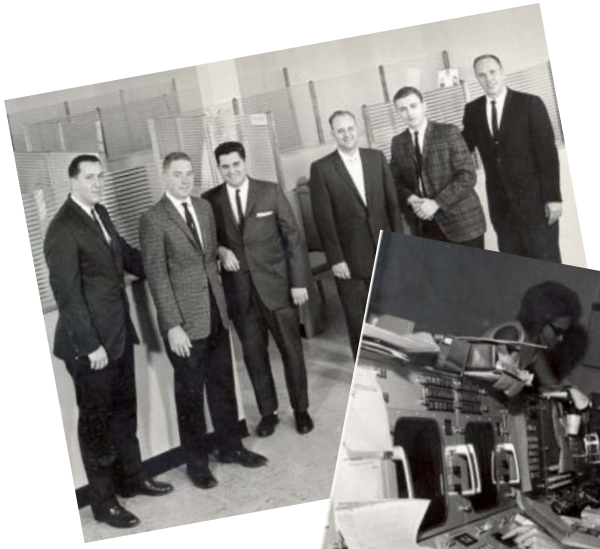


Liquid Carbonic - 1960

Gemini MCC - 1965

Test subject – late 1960's

Observations on Hardware and People

- If you're conscious most of the time, you'll start to notice patterns recurring
- I have noticed that the interaction of people and hardware produces predictable results in the case of hardware, and often unpredictable and uncontrollable results in the case of people
- I have formulated a number of observations, maybe you could call them laws, based on my fifty plus years of continually making mistakes and living with the consequences
- I have loosely grouped them into two categories: Hardware and People

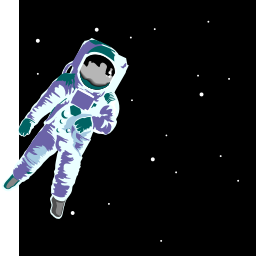
Hardware

- DESIGN
- A hardware design is someone's estimate of what it will take to do a job
  - It will always be wrong, because what we want tomorrow, or next year, is not what we said today
- There are two basic rules of design:
  - 1. Put in plenty of margin
  - 2. Hide it so that managers can't find it
- There are two basic ways to design:
  - Start with everything, and weed out
    - **Up side – you get lots of features, and, hopefully, margin**
    - **Down side – you get lots of "nice" things which can pace your schedule and ruin your budget**
  - Start with nothing and add in
    - **Up side – every feature has to be justified, and it's a lower cost**
    - **Down side – you may not have enough margin**
- Make sure that your specs widen as you go from component to system
  - Especially true for time-dependent responses

HARDWARE

- DESIGN
- The unspoken but primary purpose of a design review is to show the designer how far wrong he is
  - The provider, not the customer, is the primary beneficiary
  - Sometimes the review needs to be held before he's ready so that he can find out just how not-ready he is
- Hold a major design review just before – never just after – a holiday period

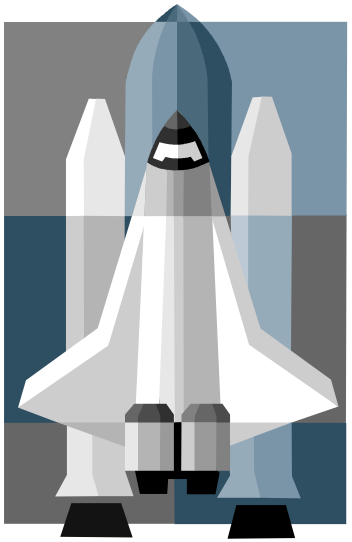
Hardware



- Automatic systems should have a manual back-up
  - **Things like temperature control, mode selection, alternate comm modes**
- Try and use stainless steel in wet environments
  - **Sure, aluminum is lighter and can be coated**
  - **COATINGS WILL BE BREACHED**
- Simple designs can be made rugged, reliable and forgiving, but they usually lack flexibility and can be heavier
  - **You have to decide the balance**

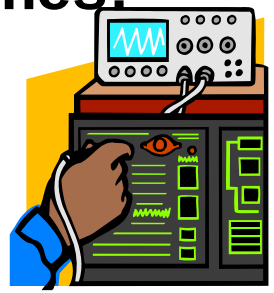
Hardware

- **Hardware always does what you tell it to do – the problem is figuring out what you told it to do**
  - **The laws of physics work 24/7**
    - **There is, though, an element of randomness**
  - **EMU fire of 1980**
  - **Challenger**
  - **Columbia**
- **Laminates delaminate**
  - **Try to go with single-element**
  - **Something always gets between the layers**
- **Coatings uncoat**
  - **Moisture or something will loosen it**



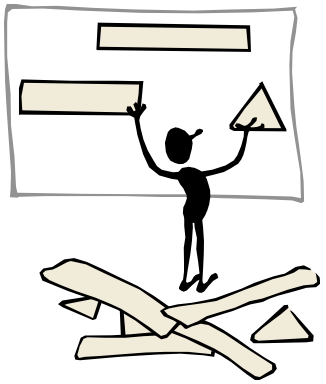
Hardware

- **TESTING**
- **Be ready for the answer when you ask the question**
- **When you test, there are three possible outcomes:**
  - **You get the answer you want**
  - **You get the answer you DON'T want**
  - **You get an answer you don't understand**
  - **Two out of the three are bad**



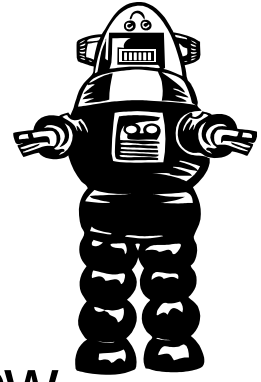
- **Every test should include the following information:**
  - **The configuration of the test item – relatable to flight**
  - **Pass/fail criteria or expected result**
  - **What was done**
  - **The results**
  - **What the results mean**
- **There's a running battle between test and analysis – the best of either is the combination of both**

HARDWARE

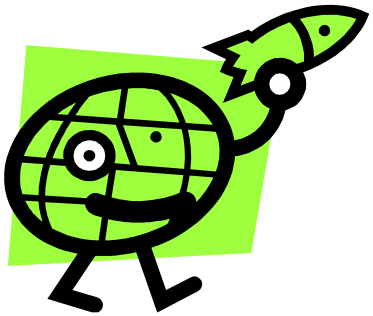


- CHANGES
- All changes have a bad side – hopefully, the good will outweigh the bad
  - Sometimes, the bad side consists simply of learning the change in hardware personality
- Beware of "bundling" unnecessary ("nice") changes along with required changes
  - Better is the enemy of good (enough)
- The most important question you can ask about a change is: "Would I fly without it?"
  - Watch out for the Safety trap:
    - **If you say the change is needed for Safety, the logical question is "Have we been unsafe all this time?"**

Hardware



- Try and not have more than a couple of new (read: unproven) technology challenges in a major system – and have a backup (back-out) for those
  - It can be disastrous to pursue too many new paths without a fall-back approach– any little glitch in any new technology area can pace your whole program
- Classify features as: Requirements, Desirements and Desires
  - Ask “Would/Could I fly without it?”
  - Go as you can pay



Hardware

- DEVELOPMENT
- You WILL have a development unit
  - You may not start out that way, but it will happen
- The most important function of a development unit is NOT testing
  - **It is to show that you can actually build it**
- The primary benefit of a good development test program is the demonstration of margin
  - Any half-way decent design will meet the base requirement
  - **DEMONSTRATION OF MARGIN IS ESSENTIAL**
- No matter where we start, we end up living in the margin
  - **You can't live in it if it's not there**

Hardware

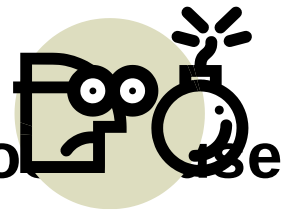
- All hardware items have a distinct personality
  - You get to know it best when using it outside the normal regimes
  - **You only get to know hardware by using it**
- Try and make as many items as possible from one production run
  - Restarts are expensive, and sometimes, results aren't repeatable
- You won't have control over lower-tier suppliers, no matter how good your system is
  - There's an entropy of rigor that increases with distance from the customer
  - Visit your vendors; get to know the people on the line

Hardware

- If Certification worked, you could fire half the contractors and three-quarters of the centers
  - Cert is someone's best guess of what the hardware will see throughout its life
  - It's always wrong – either due to error or change in requirements
  - That's why you need MARGIN
- You can't have too much hardware
  - It doesn't ask for sick leave; will work overtime without being asked; and is always cheaper the first time around

Hardware

- **FAILURES**
- **A failure results when you can't meet a SPECIFIED requirement**
- **Failures potentially affect everything of a series, and could affect others with similar components**
  - **In jurisprudence, you're innocent until proven guilty – in the case of a hardware failure, everything's guilty until proven innocent**
- **Failures in training hardware are telling you something**
- **People typically stop short of finding true root cause**
  - **Root cause is the defect in or omission of a process that controls not only your item, but other items under control of the entity**
  - **You know you've found root cause when upper management wants you drawn and quartered because you've found a flaw in an overarching process**



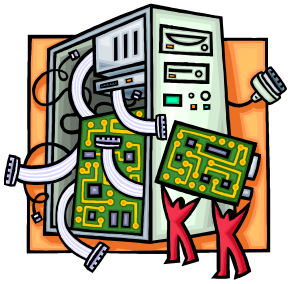
Hardware

- Any outage, failure or not, is worth investigating and documenting
- Sometimes you can't find root cause
  - Not enough time
  - Not enough money
  - Not enough management commitment
- For unexplained failures, take SOME action
  - Look at most likely cause, and address that
- Until it fails, and you find out why, nobody really understands how it works – until then, you just know how the Designer THINKS it works

Hardware

- When you've had a failure, you want to practice discrimination – find other hardware that's as different from the failed item as possible
  - It may be less time or cycles
  - It may be more time or cycles
  - Different lots; manufacturing methods

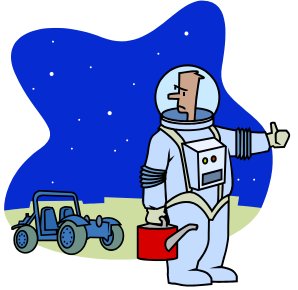
- Use items dispositioned for scrap as learning tools
  - Section them
  - Dissamble them
- When investigating a failed item, disassemble a good one first, so that you know what it looks like and can compare it with the failed item
  - **Take lots of pictures**



HARDWARE

- What's crucial is the recovery plan from a failure – five parallel elements – started simultaneously
  - 1. Identify all affected hardware
    - Maybe more than your hardware is involved
    - Need to notify potentially affected parties
  - 2. Come up with plan to support next use
    - Use hardware without no or low potential for this failure mode
    - Could be test; could be flight
  - 3. Come up with way to operate while pursuing root cause and corrective action
    - Could be same as plan to support next use
  - 4. Pursue and identify root cause and corrective action
    - Root cause involves underlying process
    - Will reside within one of the following: Paper, People, Part itself, Equipment interfacing with failed part, or Environment
  - 5. Identify viable backup plan
    - Should employ hardware with significant differences from failed item
    - Must be available in time to support when needed
    - May never be used

Hardware



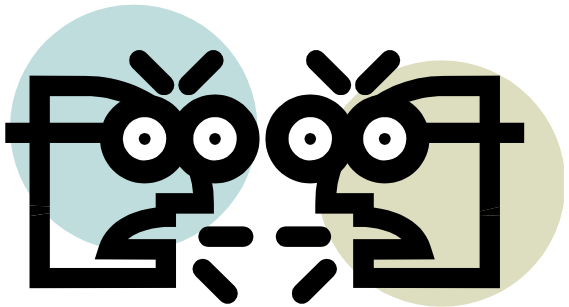
- THE CREW
- Engineers often act like all the crew has to worry about is their particular hardware
  - You may think it's easy to turn knob A; take reading B; slowly open valve C and whistle the theme from "Titanic", but multiply that by hundreds of systems
  - The crew are not supposed to be technicians and troubleshooters
- Make sure that your program is not designed to let the crew screen for failures
  - Test on the ground FIRST with hazardous fluids, environments and conditions
- Try it out on the ground first, if at all possible
  - Develop the procedure for the crew
  - Find out where it is that you don't know what you're doing

HARDWARE

- All crew-operated hardware must be able to take abuse
  - **It may look good on your desk, but can it take a blow on the corner of your file cabinet?**

Hardware

- **IN THE FIELD**
- **Make sure your hardware is flight-ready when you send it to the Cape**
  - **KSC is the neck of the funnel – don't expect them to do your work for you**
  - **If you have open work, coordinate it (Read: warn the Cape) before you ship**
  - **NO SURPRISES**



Hardware

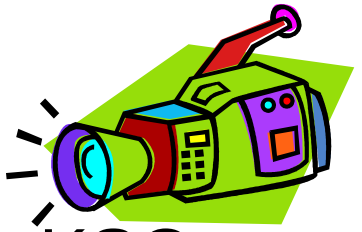
- When you're introducing a new system to replace an old one:
  - 1. You will have two marching armies until the new one is past the high-risk period
    - The "benefiting" Program has to pay for both
    - The "benefit" better be there
  - 2. You have to be alert to the possibility that THE NEW ONE MAY NOT WORK
    - Keep the old one around until the risk of getting the new one is acceptably low
    - How low is that? That's what you get paid to know

Hardware

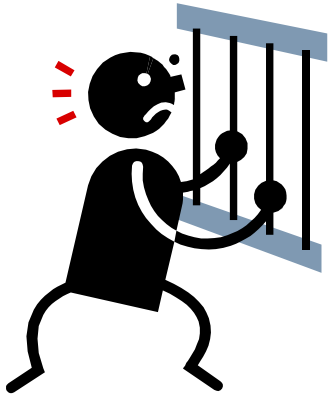
- When you're introducing a new design, try to get it in flow, i.e., pathfind it, before you absolutely need it
  - Find out its personality in the field (use) environment
  - Make sure you really understand the process that it will go through

- Whenever you disassemble a controlled unit, chances are you're going to find something wrong
  - It's a variation of being prepared for the answer when you ask the question

Hardware



- Take closeout photos before shipping to KSC
  - **Shoot the items from all angles, and in the shipping container**
- Try and mate hardware that has to fit together before it flies
  - **Not always possible**
  - **Use master tooling, if possible**
- Push back on requirements that are proving difficult
  - **Sometimes, a number is sometimes just someone's best guess**
  - **Propose alternates, e.g., root mean square for stacked component leakages**



People

- Forget “Don’t shoot the messenger” – the messenger is ALWAYS shot
  - The messenger is also the representative
  - If you can bring a solution along with the problem, the caliber of bullet may be reduced
- People respond to two primary motivations:
  - Fear (This is why we went to the moon)
  - Greed (This is the private sector’s motivation)
- There is always one person who will be found to blame
  - Management’s hands can only go around one neck
- When considering doing something stupid, ask yourself the following question:
  - “What do I stand to gain versus what do I stand to lose?”

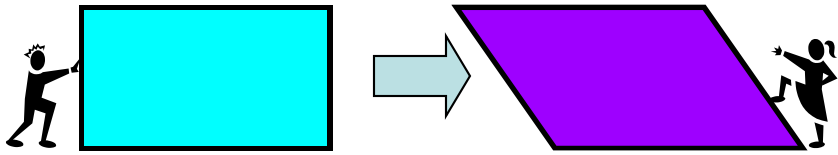
People

- Remember Stutesman's Law: "There are only these three: Cost, Schedule and Performance. You can at best control two of the three, and those will drive the third."
  - I know, I know – there are lots of metrics out there besides these, but just because you CAN measure it, doesn't mean that you SHOULD
  - SSF – example of Law violation

- Systems serve us – not the other way around
  - Beware of FORMAT over CONTENT

People

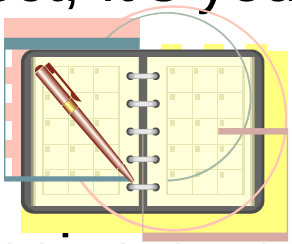
- "Think out of the box" really means "Think into a new-shape of box"
  - Making a revolution is easier than making a revolution work
  - "The box" is STRUCTURE



    - You need structure to carry out a mission
  - After awhile, STRUCTURE can become STRICTURE
  - Then, you need a new box
- You must have a system, if you want to violate the system
  - You will sometimes need to go around the formal system, i.e., to go into panic mode
  - If you operate all the time in panic mode, then you have nowhere to go

People

- The children inherit the sins of the parents
  - When you take over a project, it's yours, including the history
- Everyone has an agenda



  - All of us act in what we perceive as our own self-interest – from Mother Teresa to Josef Stalin
  - You need to figure out what's driving the other guy
- When you see a leadership vacuum, take over
  - Be jury foreman
  - Take minutes and write actions
  - Get up to the board and start asking questions

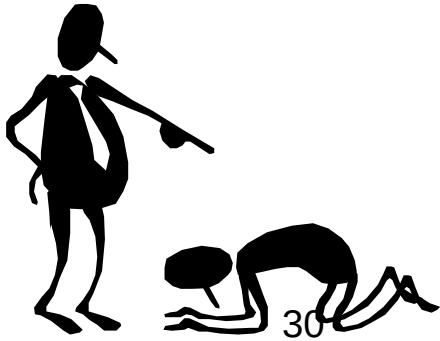
People

- Some people are successful in spite of, not because of, their ability to rant and rave
- It's not a principle if there's no sacrifice and no struggle
- You have to take it away from the engineers when it's good enough
  - Enough margin
  - Satisfies all requirements, and as many desirements and desires as you can afford
- Engineers are hopelessly optimistic: "Give me another month; another pound, and another $500K…"

People

- Be willing to work harder than the other person
  - If you bluff, better be ready to be called
  - Much can be accomplished in a meeting starting at 4:30pm on a Friday before a 3-day weekend

- There are two roads to power: Authority and Influence. Authority is limited to official scope; Influence is limitless
  - One type of influence is intimidation

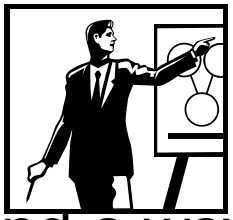


People

- Keep daring your boss to prove he is, and he will
- If you insist on pouring a gallon of gasoline on your head and asking for a match, someone will eventually oblige
- Rarely have I gotten in trouble by saying too little
  - Answer only what's asked when you're talking to the IG
  - Stop talking when you've sold it
- The worst thing that can happen to you is to have good luck early in your career
  - You begin, maybe unconsciously, to expect it
  - You get arrogant

People

- Thoughts on Meetings…
  - Some people's career consists of going to meetings and sharpshooting from the back of the room
  - Always be one to two questions deeper than your charts
  - The greatest compliment is when the chief goes to sleep during your briefing
  - When you're briefing, talk off the charts –don't read them
    - You're selling confidence in you
    - They can read the charts

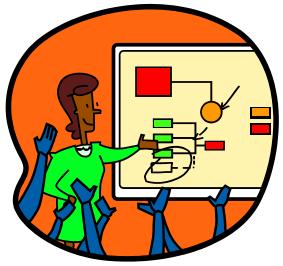


  - At the start of a meeting, try and find a way to ask "What do we want to be the product of this meeting?"
  - Have a "Get off the stage" chart
    - Don't just end it
    - Have some sort of wrapup, message, summary, SOMETHING!

People

- Cultivate your boss', boss' secretary or Administrative Assistant
- Find out who went in before you, and what happened
  - You'll inherit the consequences, good or bad
- Sometimes you have to tell the boss what he, or she, doesn't want to hear – sorry about that
- Remember, you know about people only what you see – you have no idea of what their lives are like outside the arenas in which you jointly participate
- Some people think that when you disagree with them, they need to explain it to you again, only LOUDER…and again…and again

People



- If you can't put it on a single 8-1/2" x 11" sheet, you can't manage it
- Never be more straightforward than the people you're dealing with
- Work and life in general are types of games: There are rules (which change); prizes; penalties; winners; and losers
  - **Work and life are not necessarily fun games, BUT**
  - **You can introduce a measure of fun (but don't get caught enjoying yourself)**

People

- All assigned actions should have some common traits:
  - Assign to a person, not a group
  - Have a definite product
  - Have a definite due date
  - Assign someone to follow up on actions, and DOCUMENT THE METHOD AND/OR PRODUCT OF CLOSURE

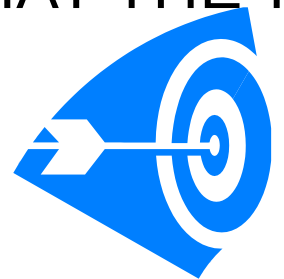
- In the best functioning teams, you can't tell who is wearing what badge
  - This doesn't mean that there aren't divisions of function – just that everybody is pulling together

People

- CONTRACTS
- Everybody hates ‘em; everybody needs ‘em
- Make sure you pick the right kind of contract for your effort
  - Fixed Price: When you know EXACTLY (by part number) what you want
  - Level of Effort: When you don’t know at 8am what you want at 1pm – “What do I do today, Boss?”
    - **Need to have MORE TO DO THAN THE CONTRACTOR CAN POSSIBLY DO**
    - **Treat each task like a mini-fixed price contract**
  - Award Fee: When it’s worth something to you to get it better or earlier or cheaper
    - **Award Fee often used to punish**
    - **Contractor needs to be shown the path to a grade of 100**
    - **In Award Fee parlance**
      - **A grade of “Good” is BAD**
      - **“Excellent” is GOOD**
      - **The contractor has to be HIGH EXCELLENT**
      - **Constant Communication throughout the period is VITAL**
        - » **Don’t wait 6 months to tell him he’s LOUSY**

People

- Contracts (cont'd)
  - Incentive Fee: When it's worth A LOT to get it sooner, better, cheaper
    - You will have a target
    - You will have penalties for missing
    - You will have rewards for exceeding
    - These work best if you know EXACTLY what you're buying
    - MAKE SURE YOU AGREE THAT THE TARGET IS REALLY THE TARGET



People

- CONTRACTS (CONT'D)
  - Fixed Fee: When you don't know what you want, but are willing to be flexible about what you get
    - Very subject to abuse
    - Can result in uncontrolled changes, overrun
- When contemplating a Gentlemen's Agreement, remember the following Rule:
  - THERE ARE NO GENTLEMEN

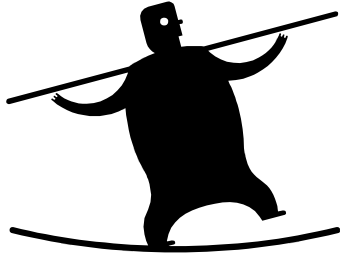
People

- NEGOTIATING
- It is vital that both sides start at the same point
  - Numbers of units; time available; technical requirements
  - Watch out for the guy who starts from an unreasonable position, and then brags on how much he's changed, and how little you have
- Keep back a decision-maker from the day-to-day fray
  - Your point person will, sooner or later, get "used up" in adhering to a position
    - They get identified with a stance
    - You need some "end run" capability
- Don't get hung up on principle (Read: loss of face) when you're only a few dollars apart
- You better have some margin in when you start, and plenty left when you end negotiations

People

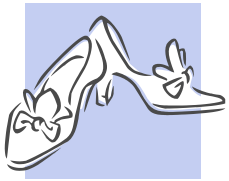
- Email is not mail
  - No expectation of privacy
  - Once you hit “Send”, assume it eventually goes to God
  - People say things in email that they wouldn’t say face to face
  - Before you react to a hot email with an equally hot reply, think about the phone first
- All the smart phones, pads and computers are just tools – they don’t create a thing
  - Your brain, a pencil, a piece of paper and some quiet time make up the best creative system ever devised

People

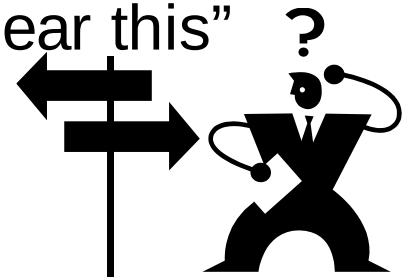


- A large part of what you do is manage risk
  - Cost, Schedule and Performance
  - The tendency is to want zero risk (impossible)
  - The reality is to recognize risk, and take some sort of action to manage or mitigate it
- Ask “Not How, but What If…?”
  - Again – you need to be ready for the answer
- The best managers say: “Don’t TELL me; SHOW me.”
- Watch out for the Challenger Trap
  - They said “Prove to me it’s NOT safe.”
  - They should have said “Prove to me it’s safe.”

People

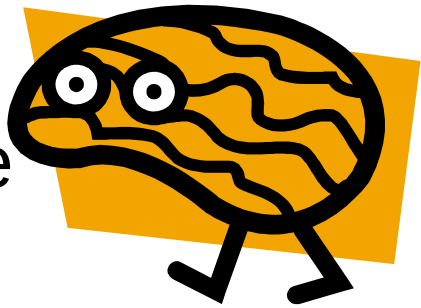


- You can stand in your boss' shoes, but not wear his (or her) hat
  - Figure out what the boss wants and needs to hear
  - Know the "hot buttons"
  - DON'T make his decisions for him or her
    - Present options, even unpopular ones
    - Make a recommendation
    - DON'T decide "He/She doesn't need to hear this"
    - GIVE THEM THE BENEFIT OF YOUR RESEARCH
    - DON'T DECIDE FOR THEM

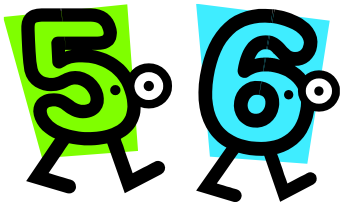


People

- Understand the functional characteristics of the Nominal Upper Management Brain (NUMB)
  - It sees no color – only black and white
  - It understands only zeroes and ones
    - You made it (1)
    - Or you didn't (0)
  - It is a cold sink, constantly requiring warmth
    - It gets its warmth from YOU
    - You give warmth by convincing management that you have your arms around the problem
      - That relieves them of the responsibility of doing your job for you
      - It lets them manage



People



- THE NUMBER IS THE NUMBER IS THE NUMBER
  - A weight; a date; a cost; a volume – whatever
  - YOUR INITIAL STATEMENT OF A NUMBER IS CARVED IN STONE – what may be your tombstone
    - It is a stick with which you will be beaten
  - These caveats DO NOT MATTER:
    - "This is just a ROM…"
    - "We haven't scrubbed it yet…"
    - "Don't hold me to this…"
  - Changes, failures, program stretchouts, things beyond your control DO NOT MATTER
  - Your only salvation is….MARGIN (hidden, of course)

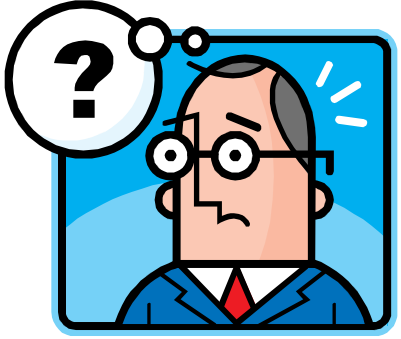
People

- Take a ride on your hardware, if at all possible
  - If you're a rocket engine engineer, OK, that's tough
  - But if you're a suit or PLSS engineer, it's much easier
  - It's a great feeling when you're the only one in the room that knows what it's like to be in a suit

People

- Your signature means something
  - **Let those above you know what it means**
  - **Be aware that the higher you are, the more accountable you are**
  - **OJ won the criminal case, but got nailed by the civil suit**
- The tendency is to want to produce an engineer with a microwave – you have to use a crock-pot
  - **It takes years of making mistakes and living with their consequences to produce a good engineer**
- You can't reason with a fanatic, a drunk or a bureaucrat
  - **Don't waste your time**
  - **Find some way around them**

People



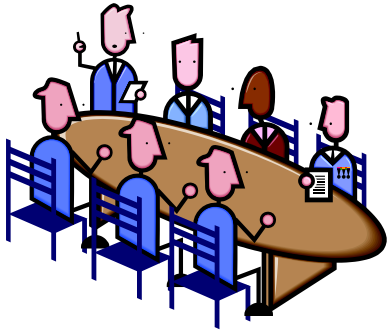
- It's hard to take advice on health from a fat doctor who smokes
  - Consider the source and then make up your mind
- Never believe the first story
  - Try to get validation before you start blabbing it all over the place, BUT
  - Get to your boss with SOMETHING before he or she hears about it from THEIR boss

PEOPLE

- When trying to unsell on Tuesday the story you so convincingly sold on Monday, be prepared for this response:
  - "Why should I believe you today when you lied to me yesterday?"
  - BE SURE WHEN YOU GO IN THE FIRST TIME; WHEN GOING BACK, BETTER HAVE NEW DATA!

People

- **There are three ways of dealing with unwanted people with whom you are afflicted**
  - **1. Stiff-arm them: Ignore them; don't tell them about meetings; don't return calls; leave them off distribution**
    - **Pro: You may get them so frustrated they'll give up**
    - **Con: You spend time trying to stymie them; also, they may bring down management wrath on you**
  - **2. Pay lip service to cooperation: Give them the absolute minimum; when possible, exclude them**
    - **Pro: Same as above**
    - **Con: Same as above, but they probably can't prove you're not cooperating**
  - **3. Bring them fully on board; ask them to help**
    - **Pro: You may be surprised at what they can bring to the table if they feel valued**
    - **Con: Can't think of one**



People

- If you're dissatisfied with your job, there are really only two sensible options:
  - 1. Figure out what YOU can do to improve the situation
    - **You're probably <u>not</u> going to change others**
    - **You <u>can</u> change yourself**

    <u>OR</u>
  - 2. Leave
    - **If you are dissatisfied and you stay without resolving the situation, you make life intolerable for yourself and others**

People

- Never pass up a chance to travel to other sites, contractors and, in particular, vendors
  - Visit the people who actually design and build the parts you're responsible for
  - Build "dotted line" relationships
    - **Do favors**
  - INCREASE YOUR INFLUENCE
- Have some ideals, and live by them
  - There's plenty of time to get cynical

People

- Your boss may seem stupid to you, but there's a reason he or she is in that slot…try and figure that out before you judge

- When you hear something that's bad, don't act until you CHECK IT OUT
  - How hard is a phone call?

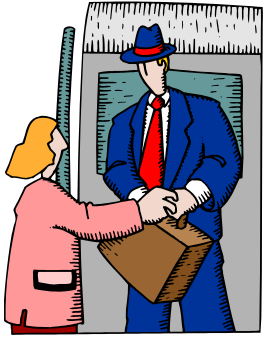
- It is so simple and so important to give credit
  - Anybody can complain, and most do
  - Giving credit is cheap, easy and so beneficial, especially for someone's idea

People

- Beware of the "Good Old Boy" Systems
  - They're not written down
  - They're usually not even known of outside the immediate area
  - WHEN THE GOOD OLD BOYS LEAVE, SO DOES THE SYSTEM
- When something is <u>important</u>, but not urgent – DO IT ANYWAY
  - Something important but not urgent becomes both important and urgent

- All time is not equal: a month in development is much longer than a month before flight
  - You've got control in development; you don't after it ships

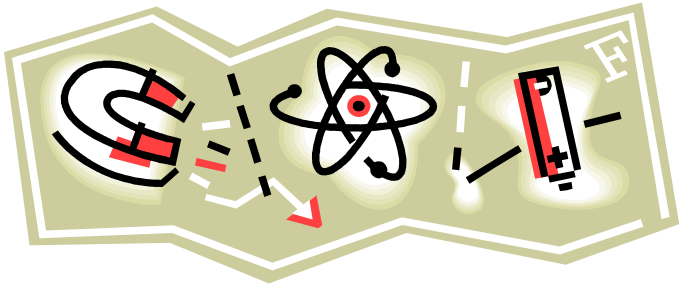
People



- Working 8 hours a day, five days a week won't get it done
  - Somebody, somewhere gets ulcers to make a project succeed
- Never, ever, promise to deliver based on a schedule of 3 shifts, 7 days per week

  - Something always goes wrong
  - AT THE MOST, schedule two shifts, 6 days
  - Allow some margin for the inevitable problems

Wrap-up



- **The laws of physics work 24/7, and you always get what you asked for**
- **You only know as much about people as your experience with their actions allow**
- **Every day has the potential to be career-altering or life-changing for you**
- **Time cannot be saved or created or bought – it can only be used**
- **You have arrived, when in a room full of people, you realize that you know more about the subject than anyone else, and you also know how little you know**
- **Have fun in the game of life**
- **Use sunscreen**