HCI NASA Group

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Appendix B
Contextual Data

Contextual Models, Concept Validation, Personas, Interview Records, and Other Observations

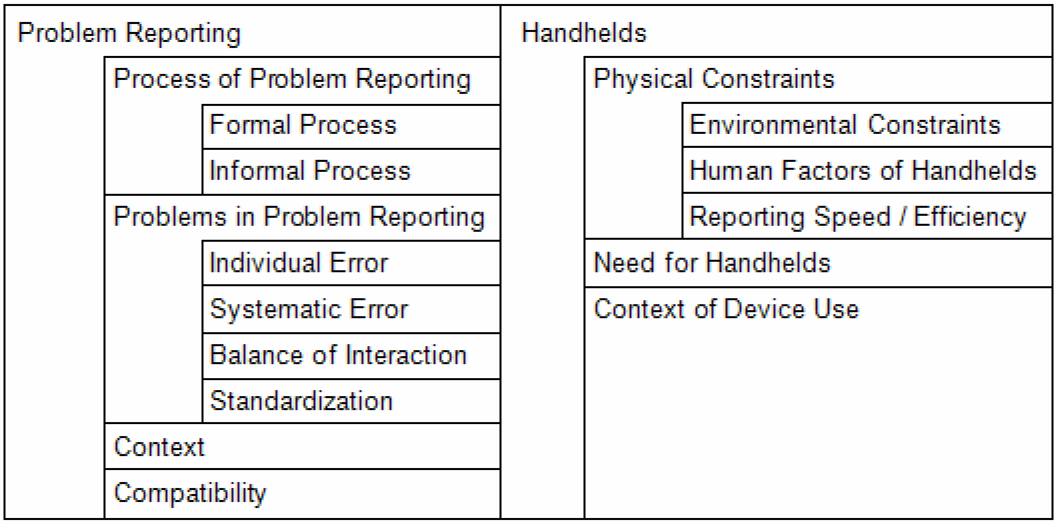
Table of Contents

First Iteration of Focus-Setting

Our first focus-setting occurred shortly after the project began, during which we identified dual foci. While this presented a split in the process of our research, it was a necessary one, and we forged ahead with this division.

We created an especially large “Problems in Problem Reporting” section in the knowledge that this was the stated need that the clients expressed as justifying our services. The “Process of Problem Reporting” was at this point vague, as we only knew that whatever that process might be, it would, like so many other social processes, likely be divided between separate formal and informal aspects.

The “Handhelds” section focused on the obstacles presented against the effective use of a mobile device, but also included a subcategory inquiring into the very need for handhelds in the first place. Although our clients went into this project suspecting that a handheld might be a likely solution, we were well aware that retaining this as an unquestioned assumption was a dangerous move. In the end this intuition was substantiated given our contextual data, which follows.



- Problem Reporting
  - Process of Problem Reporting
    - Formal Process
    - Informal Process
  - Problems in Problem Reporting
    - Individual Error
    - Systematic Error
    - Balance of Interaction
    - Standardization
  - Context
  - Compatibility
- Handhelds
  - Physical Constraints
    - Environmental Constraints
    - Human Factors of Handhelds
    - Reporting Speed / Efficiency
  - Need for Handhelds
  - Context of Device Use

Preparatory Contextual Models

Chosen for their relevance to either of our foci of handhelds or problem reporting, our preparatory CIs were accessed through our own local networks of contacts, and generally were both easy to find and very informal. Although not our real users, the trends seen during these preparatory CIs would be observed again and again throughout the project.

Steam Plant

We made contact with the staff simply by walking in and asking if we could speak with someone. We ended up meeting the evening shift technicians, who were very friendly and eager to help. This was a successful interview, as we about their maintenance and problem reporting processes. However, it would have been preferable to have a second CI with upper management, because there were certain ambiguities about the foreman's and superintendent's processes and knowledge.

We analyzed the activity involved in using a reporting book in a fixed location to enter all information about problems and problem resolution. Problems during evening shift hours are often passed on to morning shift engineers through these notations. The staff had moved to this method from a decentralized practice involving clipboards some time ago. This location of problem reporting, to which a person must return before filing a report, we came to call the "base station." The balance between centralized and decentralized problem reporting would go on to become an important theme of the project.

UPS Parcel Deliveryman

A member of our team was able to meet the participant at a point on his route and ask him about how the delivery of packages is reported. While this CI did have several minor insights relating to problem reporting, our major insights came from an artifact walkthrough that communicated the general design requirements of a portable handheld built to allow reporting to a centralized database even in extreme environments. The picture of this device, called a DIAD, became an important artifact model. (B27)

The parcel delivery inquiry was focused primarily on the context of use of the postal service worker handheld device, specifically designed for their routine needs, catering to all possibilities of breakdowns, and providing two-way communication between devices and other postal service employees, while maximizing efficiency of the work.

University Cluster Services Manager

The third interview was with a university computer cluster services manager at our university, or "CCon." A part-time worker and full-time student, it was his job to staff and help maintain a cluster of public-use computers for several hours a week. During this time it was necessary to ensure the cluster was fully functional, and he regularly addressed, corrected, and reported problems found in the cluster to a centralized database.

The participant used the network's ZMAP system to ping network computers and identify which computers were down and required checking, but this was frequently unreliable and he often depended on visual checks of the labs. Most problems could be solved by a simple reboot. When a problem was found, the internal online problem assessment website form was used to report problems and print notices to post on or near problem computers for subsequent asset checks. Part of this form was designed to question the CCon and ensure he'd already checked for superficial problems, such as detached cables.

There was also regular online paperwork that CCons had to submit. As manager, the participant reviewed the forms of other CCons in addition to submitting his own, but he knew that this paperwork was not actually used by anyone, and so regularly submitted his with blank spaces. By contrast, the junior CCons took great care to fill out their reports.

HVAC Contractor

The local HVAC contractor was independently employed with a variety of clients to install and repair heating and cooling equipment. Although his problem reporting system was largely internal to a one-man operation, this was a valuable CI, allowing us to become both more familiar with technical work and more aware of the complexity and importance of rigorous work scheduling for technical tasks.

We went on location with him at a job site and were able to do an analysis of the artifacts (e.g. multi-meter, proposal documents) and work context (e.g. residential and small commercial), as well as a walkthrough of the sequence of invoice creation and repair. An interesting issue that we came across was the integration of existing devices with other devices and reference manuals. We determined that a great deal of time was lost in checking through technical manuals, a process that could be automated.

His problem reporting system was also of interest. He would first create a list of the problems to be fixed, submit it as an invoice for approval, and then would create a list of actions to correct the breakdowns in the heating and cooling system. The invoice of breakdowns and work list were related, but distinct, a pattern we later observed at NASA.

Robotics Professor

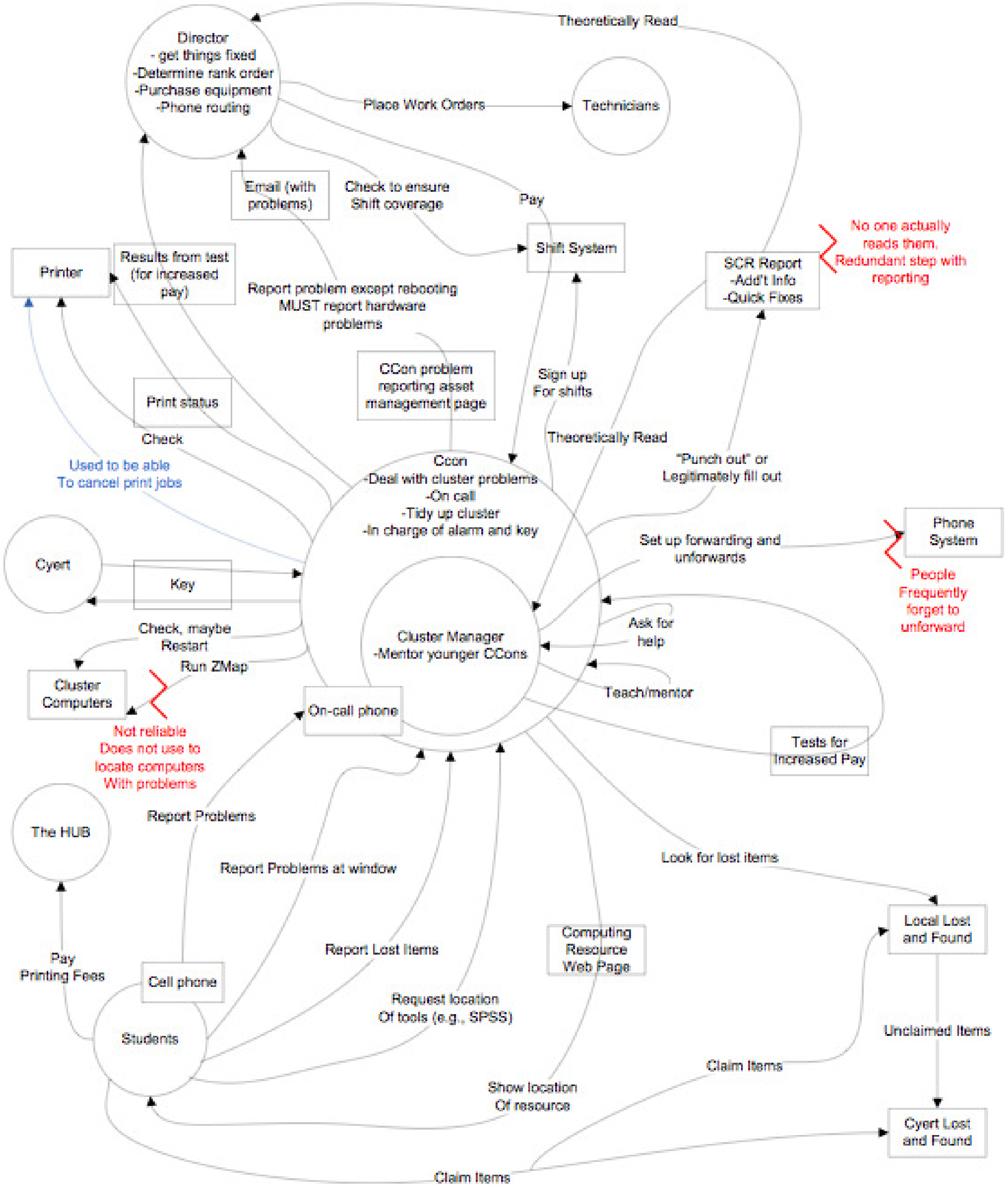
The final CI was with a professor in the Robotics department. We were surprised to discover that he didn't actually have a formalized system of problem reporting. We found this to be unusual, given both the incredible complexity of a robotic project and the fact that even a local HVAC contractor had his own problem reporting system.

While we were initially disappointed and confused, we later found that a number of different people in different situations do not report or log problems. For example, the Ames Vertical Gun unit doesn't report any problems, and neither do many research and development projects. We later came to identify a shortlist of characteristics that differentiate organizations that report problems formally from those that do not. (B66)

Appendix

Contextual Inquiry Models

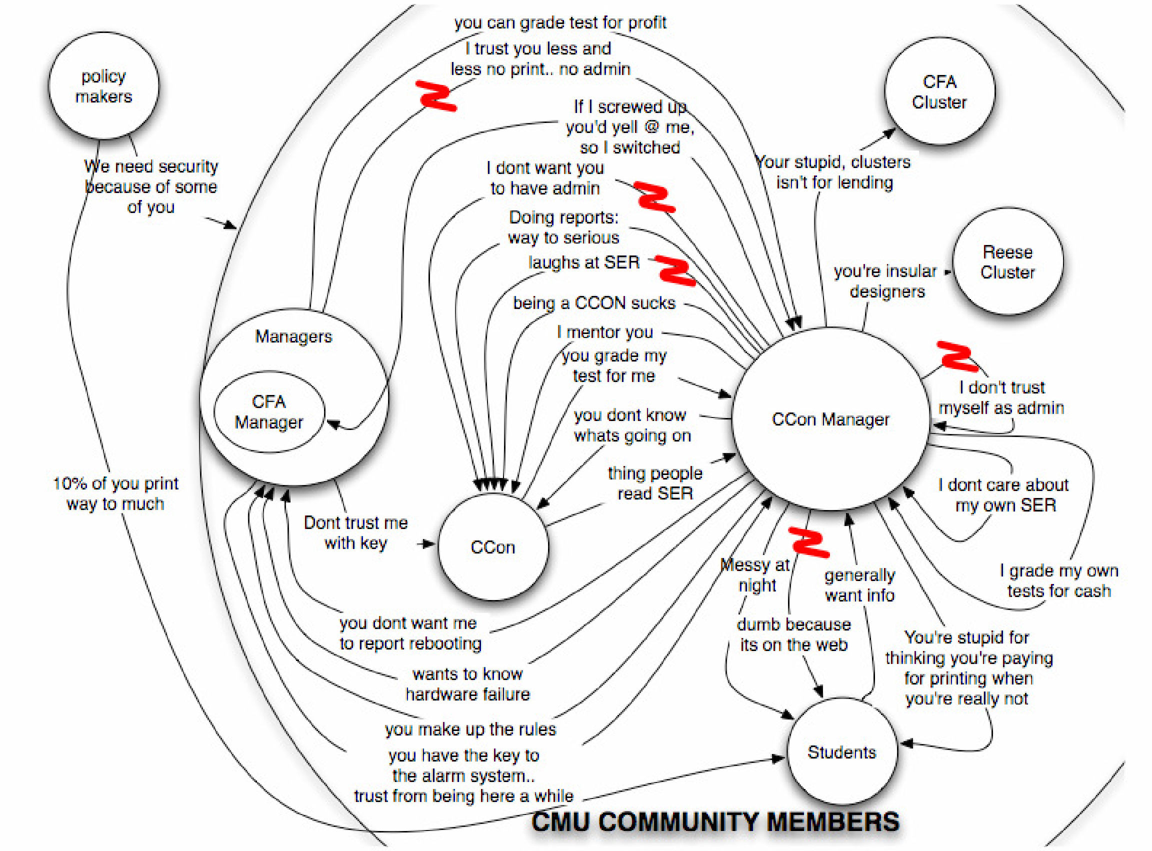
Carnegie Mellon Cluster Services -Workflow Model



Carnegie Mellon Custer Services Workflow Model:

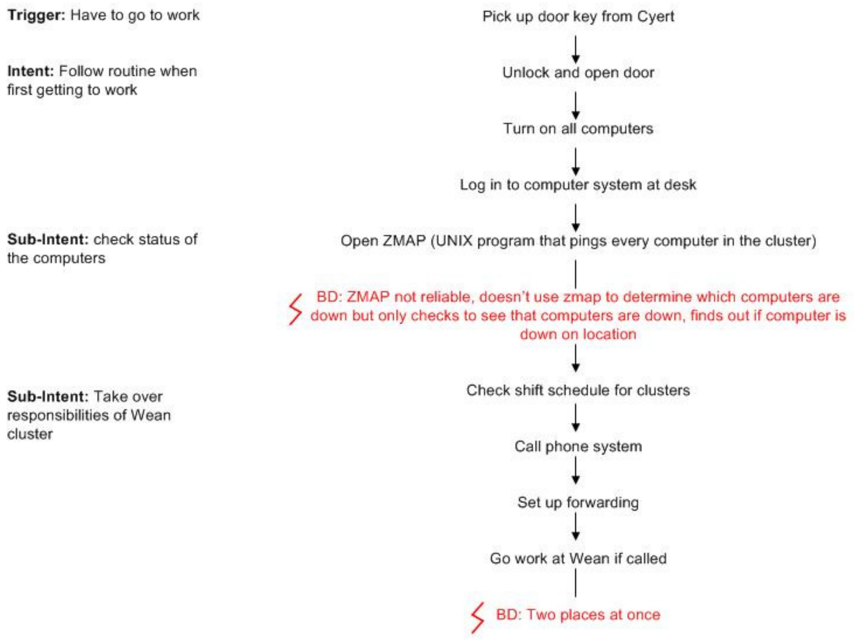
The workflow of CMU cluster services centers around the CCons, who manage the cluster equipment, remain on call, and are in charge of cluster security and access. If there are hardware problems in the clusters, CCons report this to directors who rank the problems and eventually fix them. Cluster managers mentor young CCons, and theoretically fill out an SER report of cluster problems for directors to read. In reality, directors never read these SER reports, since they are redundant with problem reporting. CCons are paid by directors and can take exams to increase their pay. CCons use ZMap to locate computers with problems in the cluster, but this becomes a breakdown as ZMap is not reliable.

Carnegie Mellon Cluster Services Cultural Model:



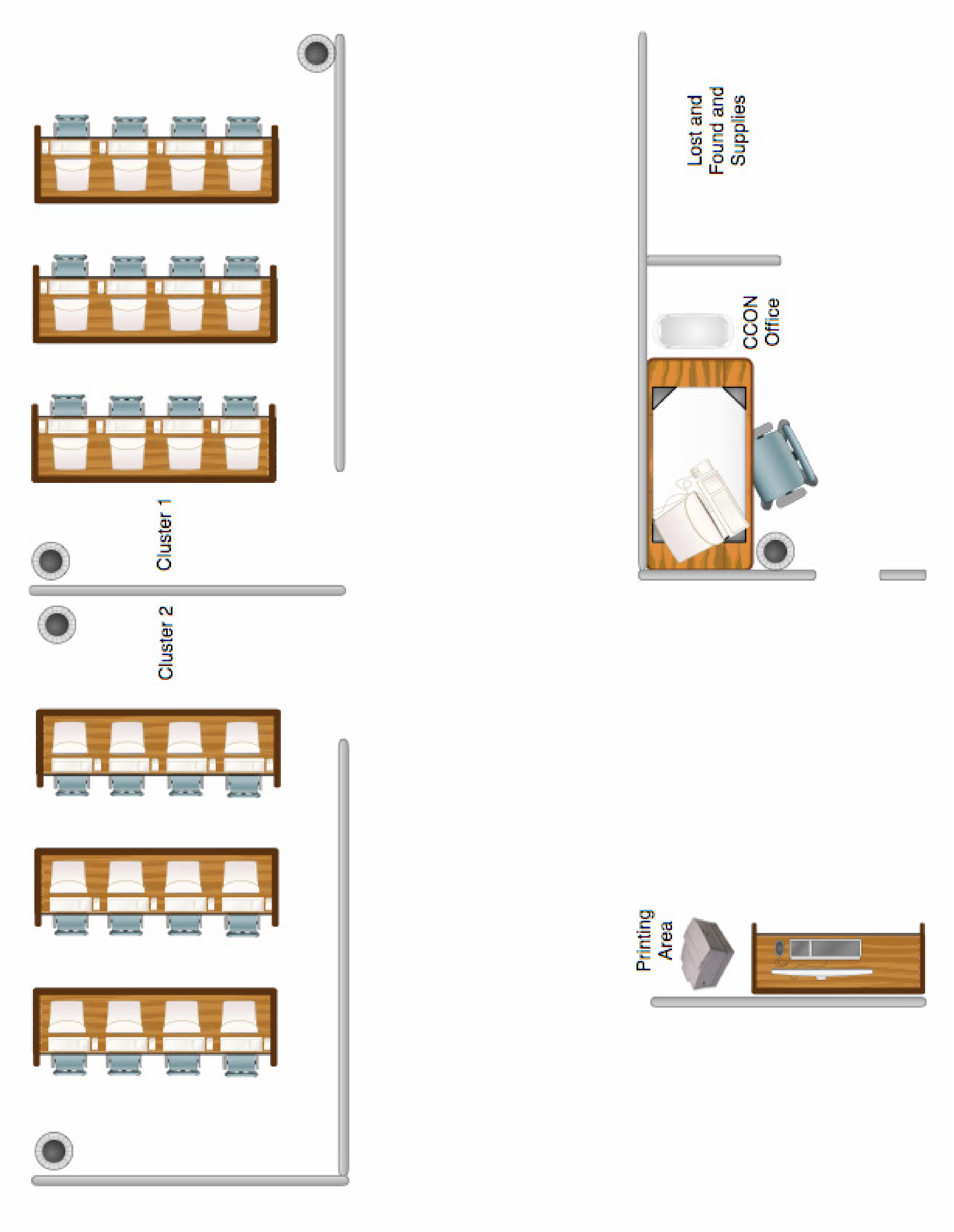
The Carnegie Mellon Community involved with cluster services is comprised of the CCon Managers, CCons, Managers, CFA Managers, and CMU students. CCons, the lowest level position in cluster services, manage clusters by troubleshooting computers and assisting students. Generally, CCons want to do their job with as little administration and hassle as possible. They dislike doing reports and don't want the CCon managers to micromanage them. CCons are supposed to fill out problem reports known as SERs at the end of their shift, but instead CCons fill out SERs for a long period of time before their pay day and tend to forget many things that went wrong in the cluster. CCon managers generally think the CCons don't know what is going on and serve as mentors for them. Managers are above CCon managers. They make up some rules and regulations for the clusters and do not trust the CCon managers. Policies related to printing are decided on by an independent CMU body of policy makers.

Carnegie Mellon Cluster Services Sequence Model:

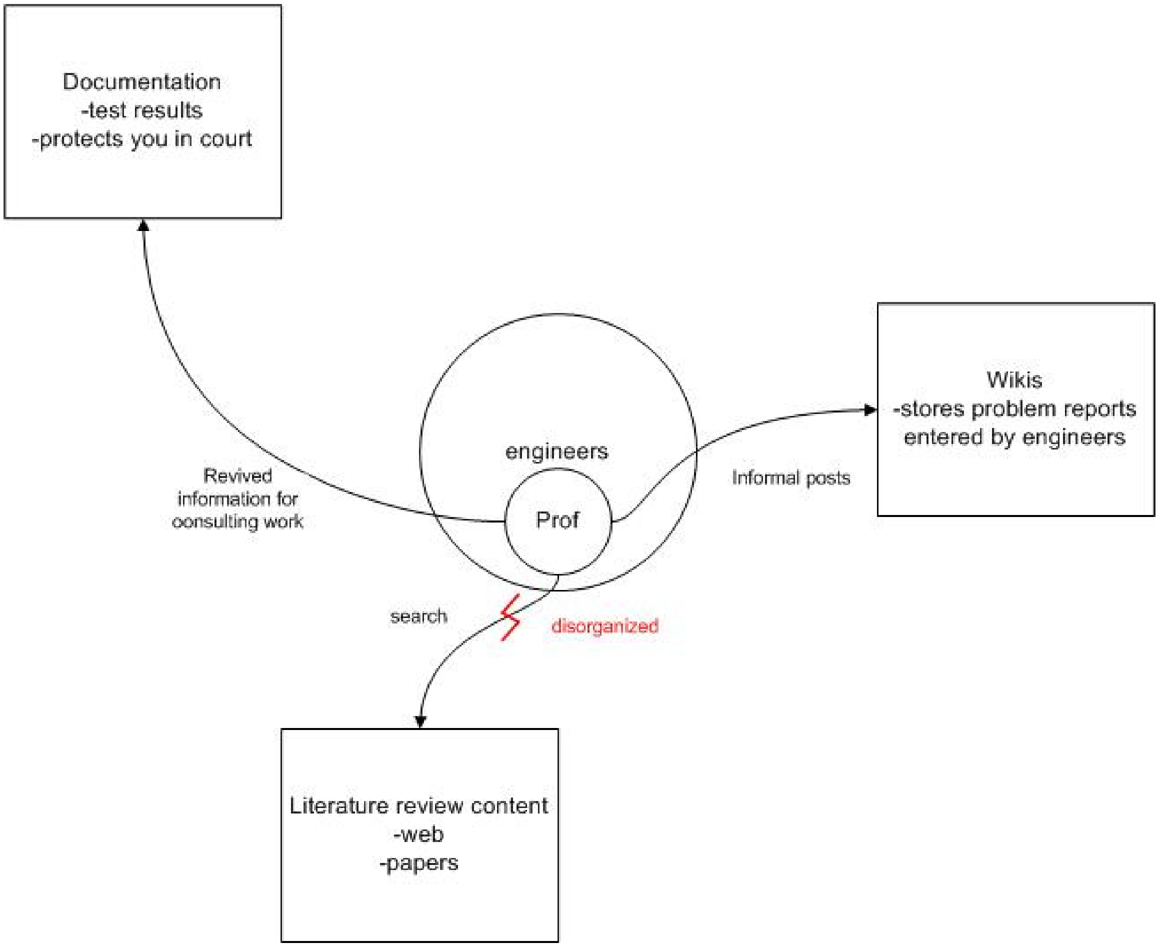


CCON Sequence #2

Carnegie Mellon Cluster Services Physical Model:

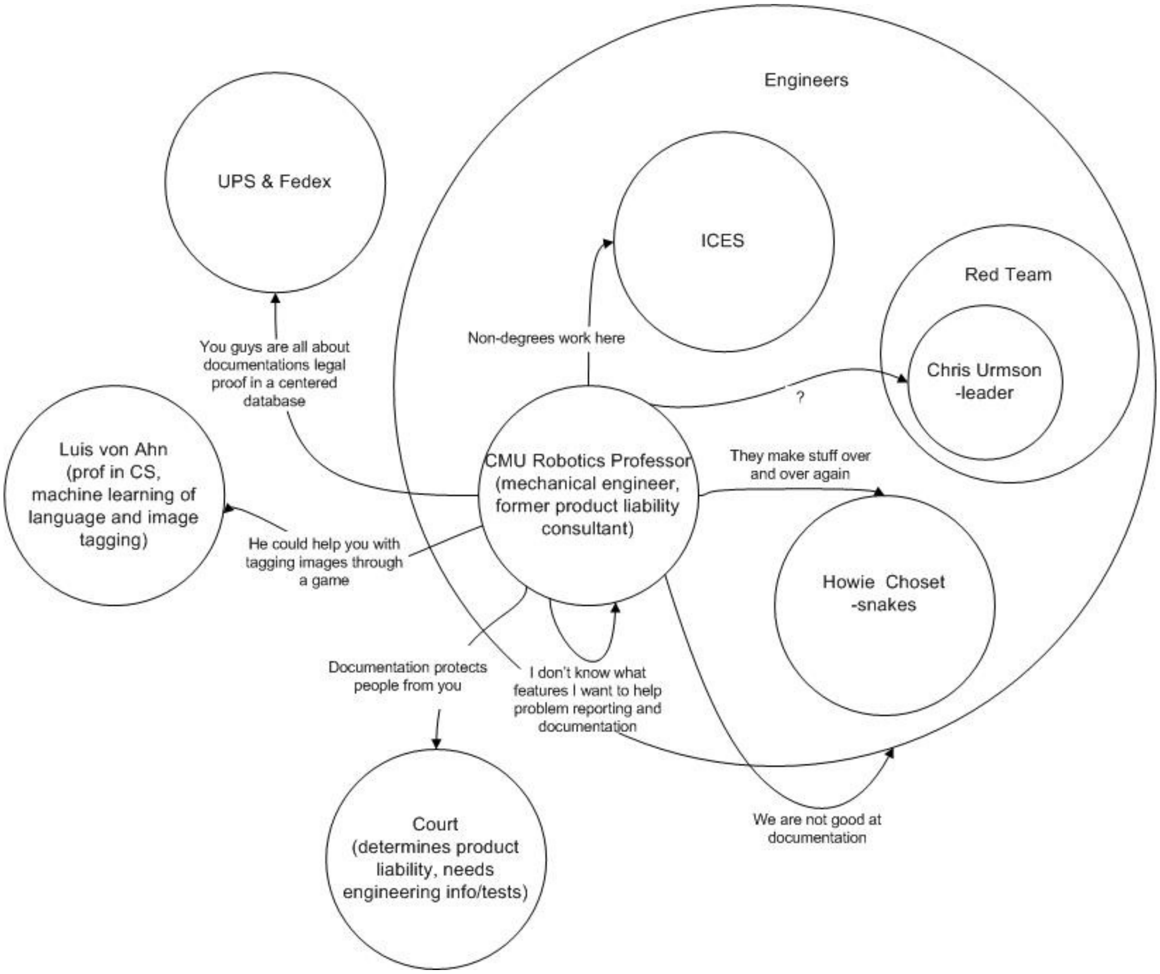


Carnegie Mellon Robotics Workflow Model:



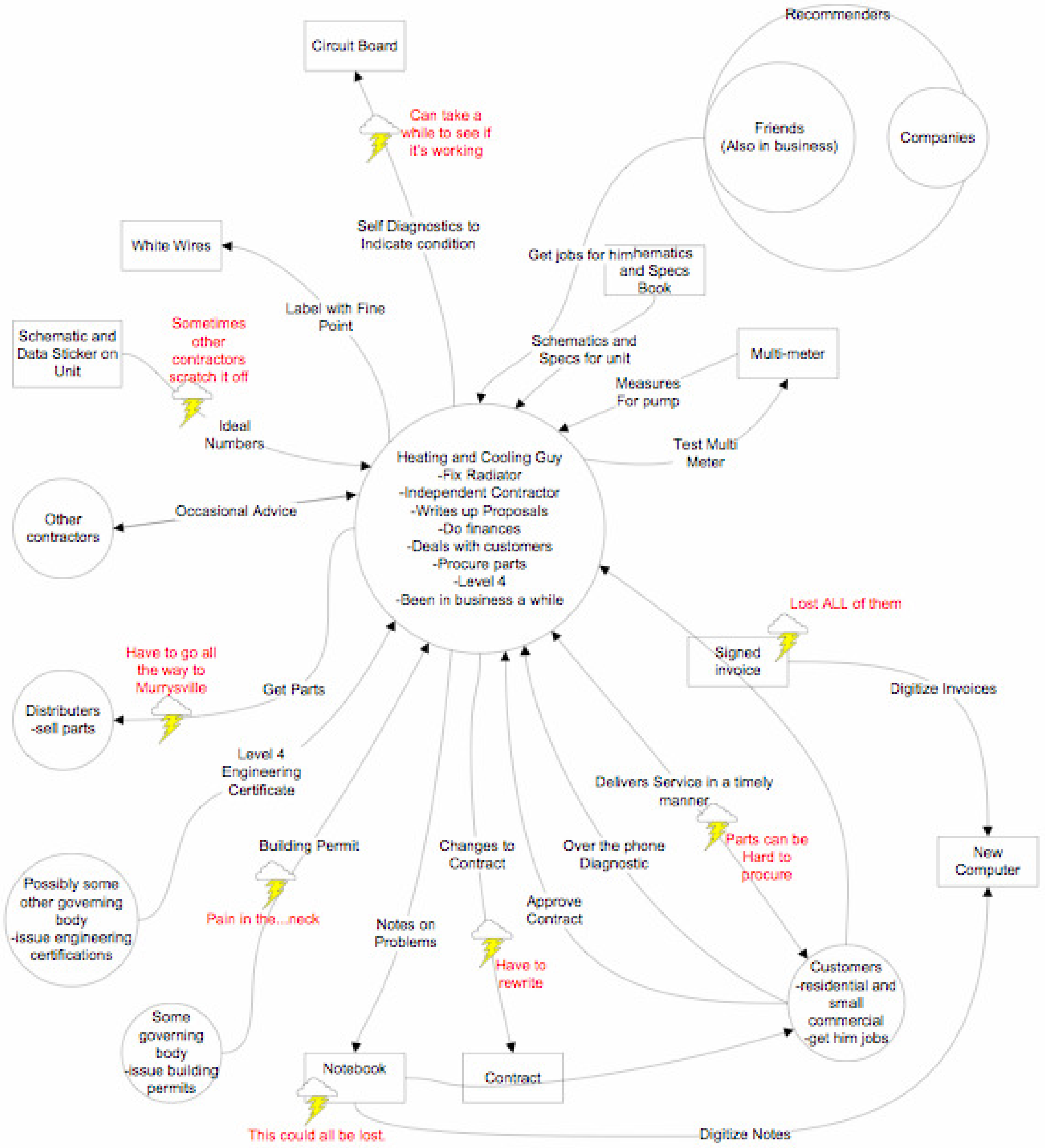
CMU robotics engineering professors search through the literature review content in a disorganized and sometimes inefficient process. The professors make informal posts to wikis which store problem reports entered by engineers. Professors also revive information from documentation for consulting work.

Carnegie Mellon Robotics Cultural Model:



The engineers of CMU robotics are divided into the robotics professors, the associate professor of robotics, ICES, and red team. The robotics professors claim they are not good at documentation and do not know what features they want to help problem reporting. The professors use UPS and FedEx for documentation of legal proof in a centered database, which protects them from going to court over product liabilities.

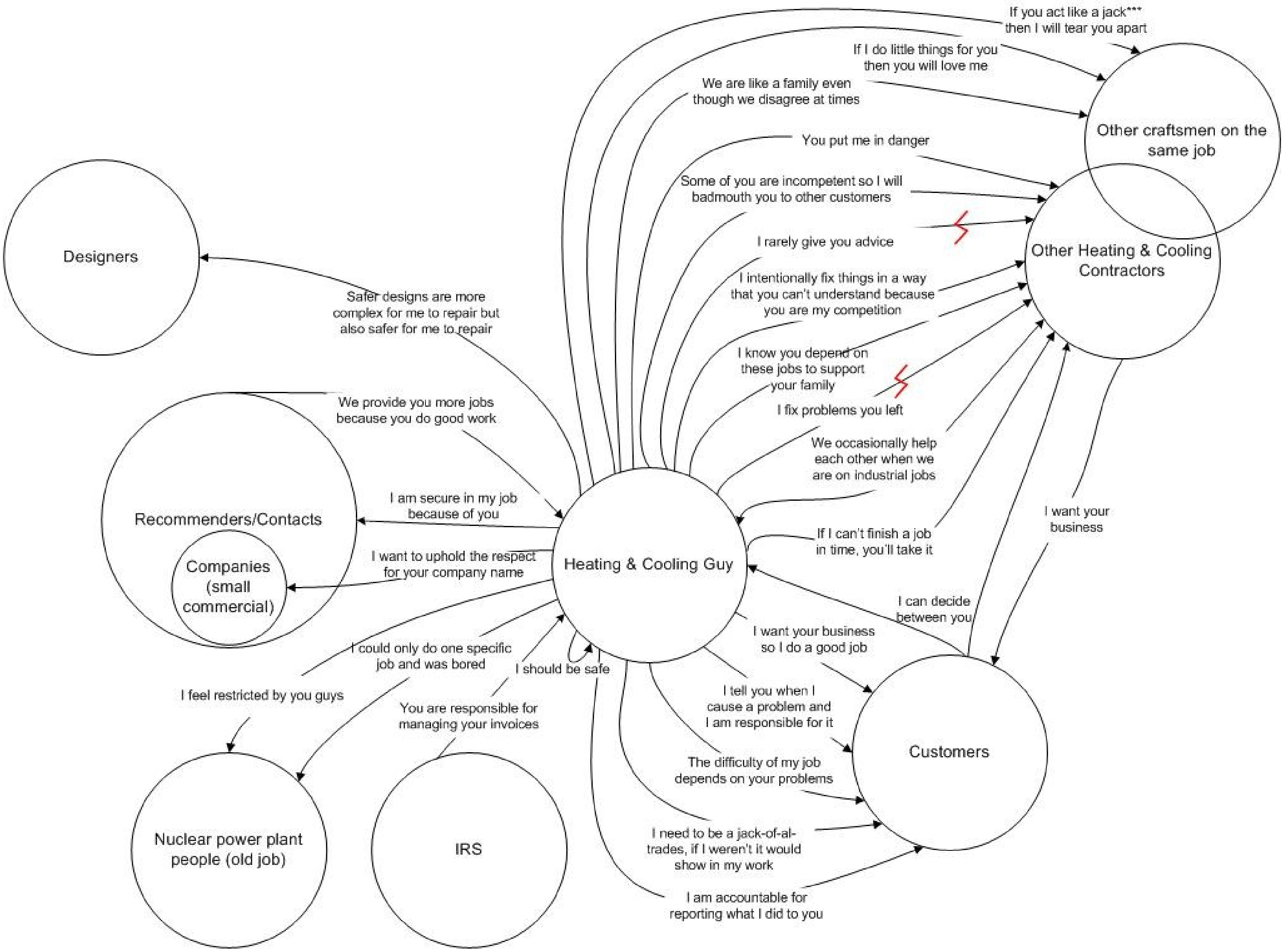
HVAC Contractor Workflow Model:



HVAC Contractor Workflow Model:

Our workflow model focuses on the repair jobs performed by an independent contractor named Dan. Dan writes up proposals for work to be done, gives estimates, works with the customers, procures parts needed from distributors, and then performs the repair work (primarily radiators). Dan gets his jobs from referrals from friends and companies. He uses a notebook to record for himself what problems are needed, a multi-meter to measure pump pressure, a kit of tools, and a phone for an early diagnosis of the problem with a customer. Some of the breakdowns in Dan's system include the time it takes to track down a part needed if his main store doesn't have it, the risk of losing his notebook and all the valuable information on it, dealing with scratched off stickers on equipment which other contractors have done to hinder his progress, and losing invoices.

HVAC Contractor Cultural Model:



HVAC Contractor Cultural Model:

Dan generally has a good relationship with his customers. He wants their business, and thus does a good job and is responsible. The problems he is asked to fix cover a wide range, so he must be a "jack-of-all-trades." Dan wants to uphold his respect in small companies, because he depends on recommenders and contacts for job security. Dan considers other craftsmen on the same job to be like a family, though they disagree. If Dan helps the other craftsmen they will be kind to him, and if he does not they'll "tear him apart."

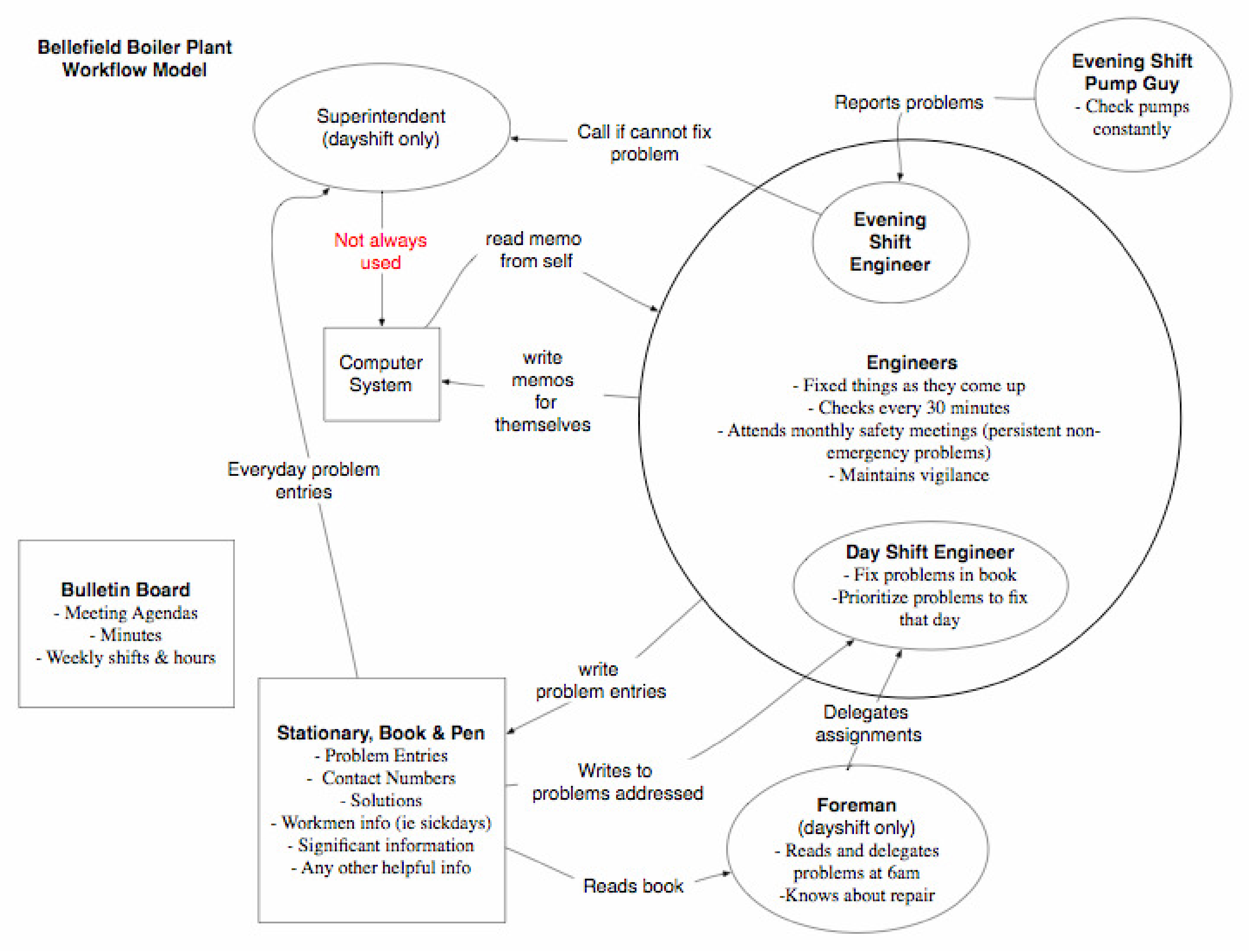
Dan believes that some other heating and cooling contractors are incompetent and put him in danger. He often has to fix problems they left and sometimes a job goes to another contractor if Dan can't finish it in time. However, Dan knows that these contractors depend on getting jobs to support their families. Contractors occasionally help each other when they are on industrial jobs.

The cultural interaction we found most interesting is that Dan described as the "dickmove." Because Dan is one of many independent heating and cooling contractors that work in the area, he is in competition with other heating and cooling contractors. For this reason, many of the contractors employ tactics to make the jobs of contractors in the future more difficult. By fixing a heating and cooling system in such a way that trips up other contractors, contractors like Dan are guaranteeing that they will be the most efficient and skillful repairman for a particular job in a particular house. An example of a dickmove is removing a schematic drawing attached to equipment so that it cannot be used as reference. Dan employs a dickmove by using only white wires, rather than colored ones, on heating and cooling units. He labels these white wires in black market with designations that he can understand. Because there are no colors to help other contractors differentiate the wires, Dan is making their job harder while not hurting himself.

HVAC Contractor Sequence Model:

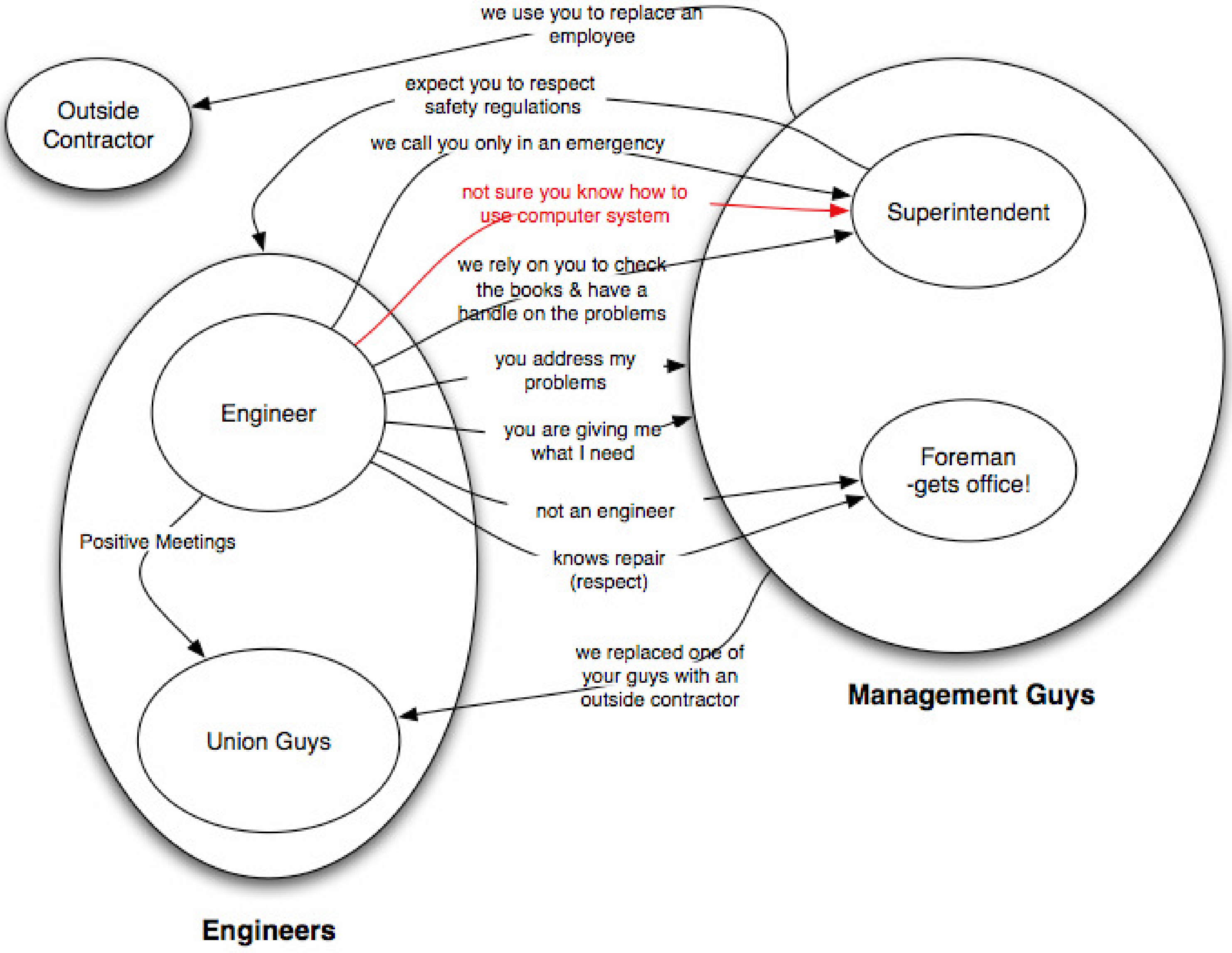
```
Intent: Fix a customer's heating problem
Trigger: Receives call, often gets work through word of mouth
While problem unsolved then {

    - Does over-the-phone diagnostic with customer, asking simple questions such as "is
    there a rattling sound?"
    - Goes to customer's house or business to check problem
    - Writes notes for himself on what needs to be done, what parts are needed
    - Goes home, types up notes into a bid for the customer which includes what needs to be
    done, how long it will take, estimated price
    - May have to get building permit at this stage
    - Person either accepts bid or rejects

        If_ rejects, end.
        If accepts, Then continue:

    Intent: Get parts needed for job
    Trigger: Written bid and own notes with parts needed
    While doesn't have necessary parts, then {

        - Goes to favorite parts store
        If: favorite store doesn't have part
        Then: drives to other stores until he finds needed part (ordering parts takes a
        long time, and customers won't wait in bad temperature for a part to arrive).
        }

    - Goes back to house with parts and blue Electrical Services Part Guide Book
    - Tests multi-meter with wire circuit to make sure it is working
    - Does hand calculations on heat, flow, etc
    - Fixes heating and cooling, labeling white wires in fine point
    }


Intent: Use working multi-meter
Trigger: Need for measurements
    - First checks wire circuit to make sure multi-meter is working
```

Heating Plant Workflow Model:



The workflow at the heating plant centers around engineers. Day shift engineers fix and maintain the heating plant equipment, working through a log book with a list of documented problems. This log book is created by day shift engineers that observe problems and by evening shift engineers and evening shift pump engineer, who record any problems they see on a thirty minute check of heating plant equipment. Evening shift engineers do not perform major repairs, but rather maintain the operation of the heating plant and record any problems they see for the day shift engineers in the log book. The foreman, who works only in the day shirt, delegates the task in the log book to engineers to fix. This log book contains problem entries, follow-up for problems, workman information, and any other communication that must be passed between shirts. The superintendent , who works only in the dayshift, looks oer the problem entries in the log book. He is also contacted if an emergency occurs in an evening shift that the engineers cannot fix. The superintendent has a computer system to record all problem reports, but the engineers believe that he does not often use it.

Heating Plant Cultural Model:



The engineers include heating plant engineers as well as union engineers. Union engineers are sometimes replaced by outside contractors by the management. Management includes the superintendent and the foreman. Engineers feel that their problems and needs are addressed well by management. They respect the foreman, because while he is not an engineer he "knows repair." The engineers call the superintendent during an emergency and rely on him to check the books and handle problems that arise in heating plant maintenance. In tern, the superintendent expects the engineers to perform well and to respect safety regulations.

Heating Plant Sequence Model:

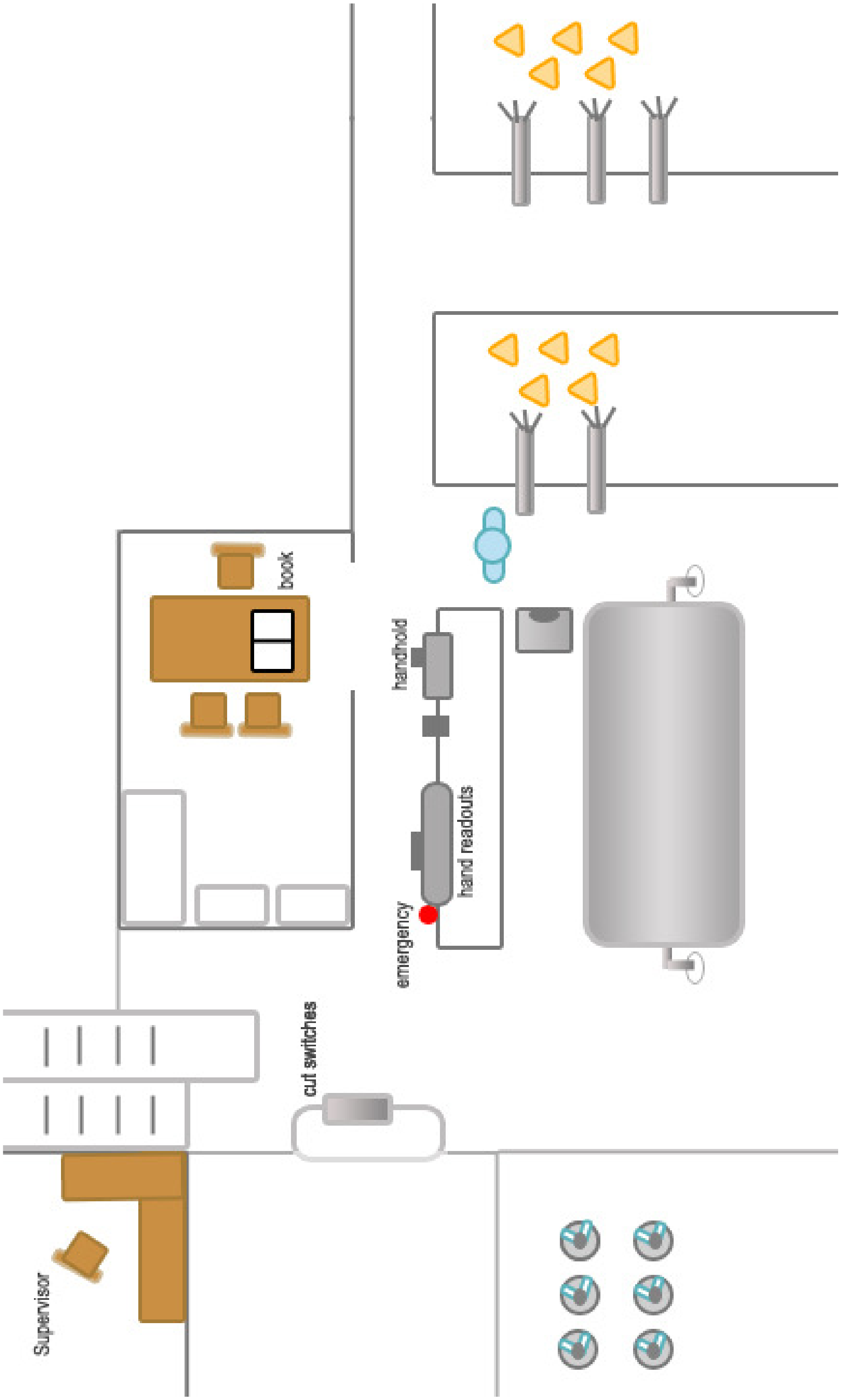
```
Intent: Keep the plant in adequate running condition for the following day shift
Trigger: Night shift
While Night {

Intent: Know of any problems within the plant
Trigger: Every 30 minutes
Engineer checks for problems

Intent: Keep the plant in good running condition
Trigger: Problem found
if Problem found then {

        Intent: Avert emergency situations
        Trigger: It's an emergency (How to tell?)
        if emergency {try to fix}

        Intent: Get help for things we can't handle
        Trigger: It's unfixable (How to tell?)
        if unfixable emergency {call superintendent}

        enter into book
        }
}

Intent: Restore the plant to ideal working condition
Trigger: Day shift
While Day {

        Intent: Understand the scope of the repair work
        Trigger: Arriving for work
        book read by foreman
        foreman delegates tasks to engineers (How does this delegation occur?)
        engineers prioritize problems (Do they keep their own copies of the list?)

        Intent: Fix all the problems, worst first
        While there are unfixed problems {
        Trigger: Problem reached in order of priority
        engineers fix problem
        }

        Intent: Record the fixes in a centralized location
        Trigger: Problems fixed OR end of working day? (Do they write after each fix?)
        engineers write fixes in book
```

}

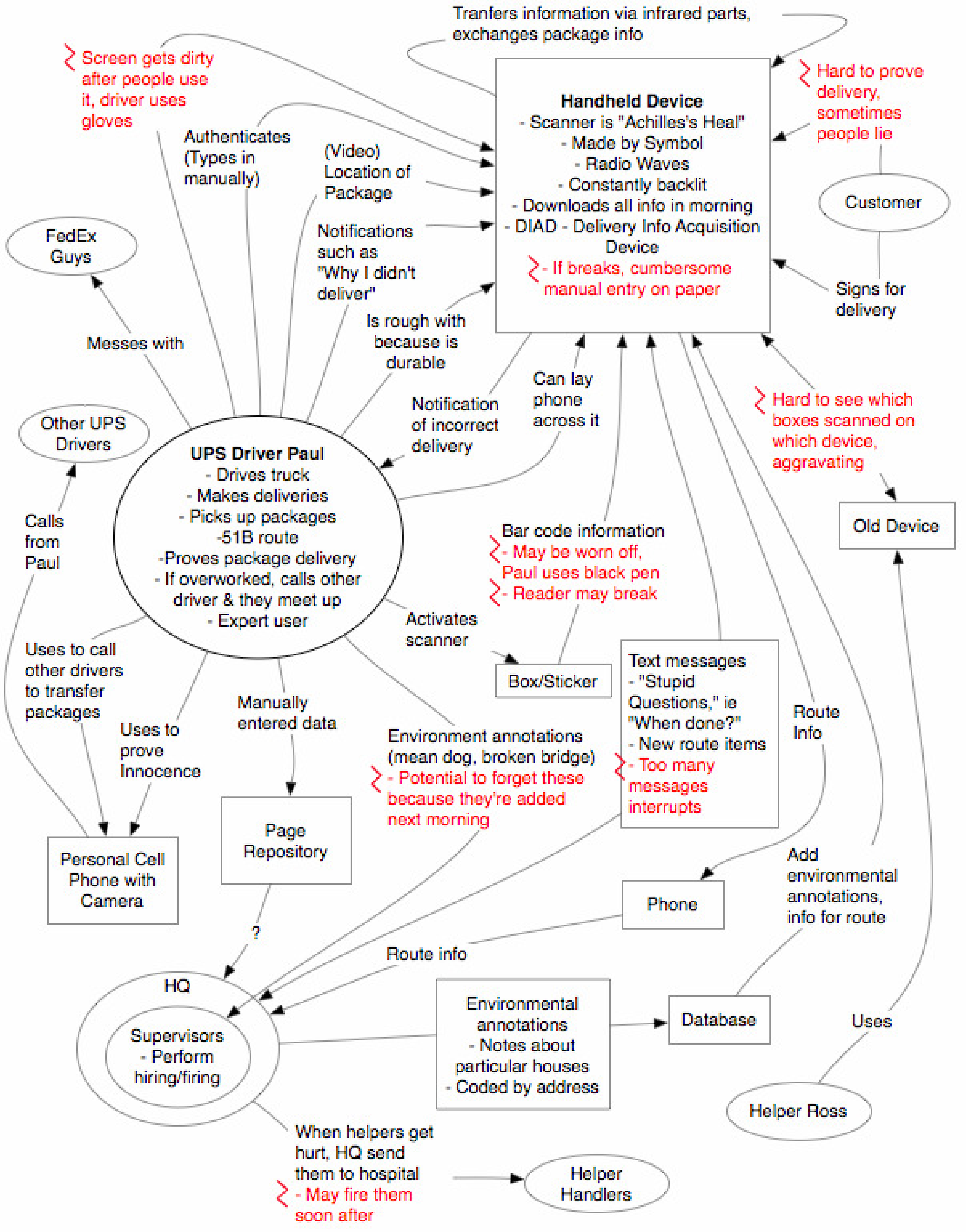
Notes:

Book is last action in the sequence, never the first (balance between centralized location/keeping on same page, and ability to carry own very accessible lists?)
Observing the start of a day shift would answer a lot of good questions
Any information on the older system of problem reporting would be useful

Heating Plant Physical Model:



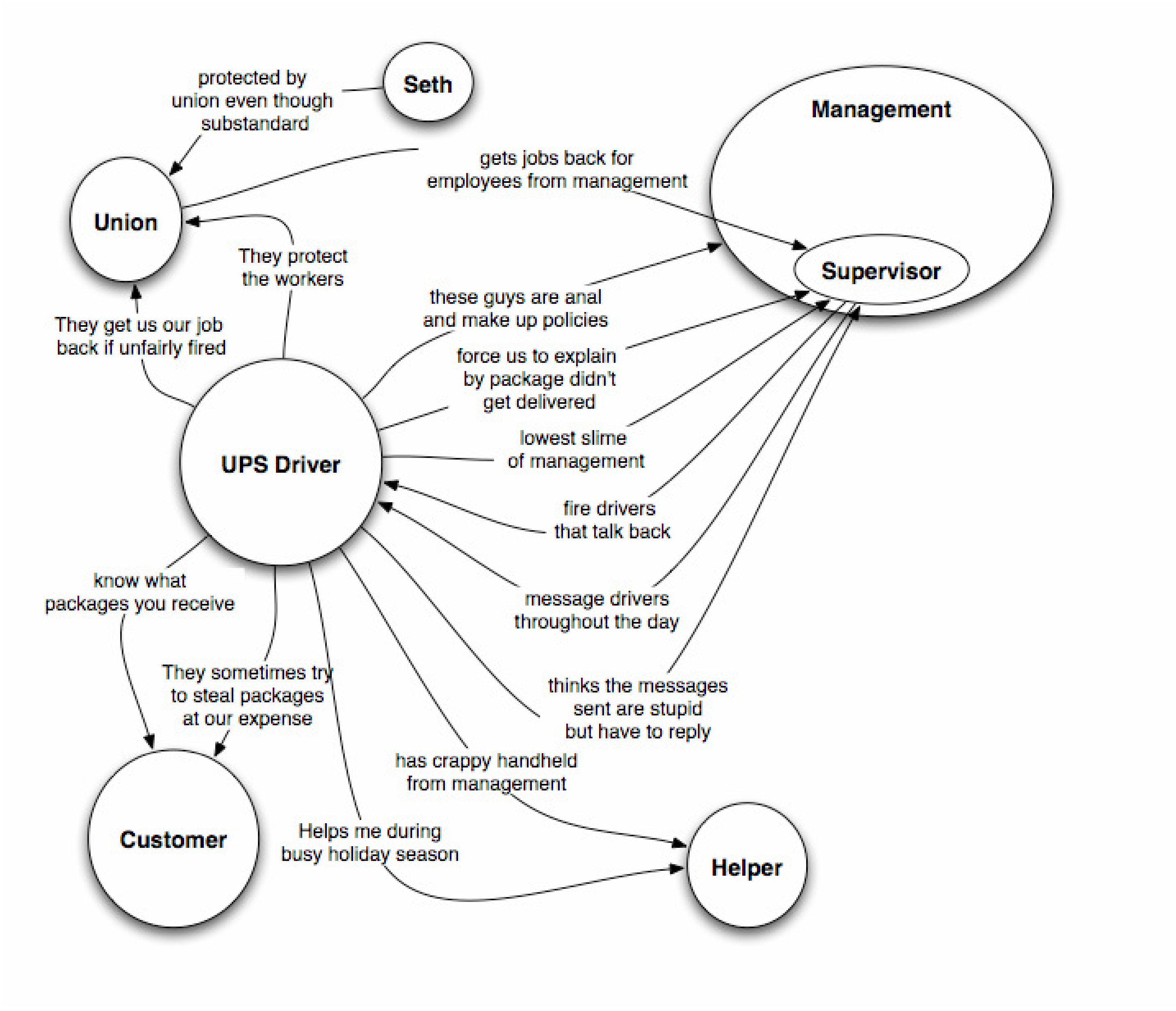
UPS Workflow Model:



UPS Workflow Model:

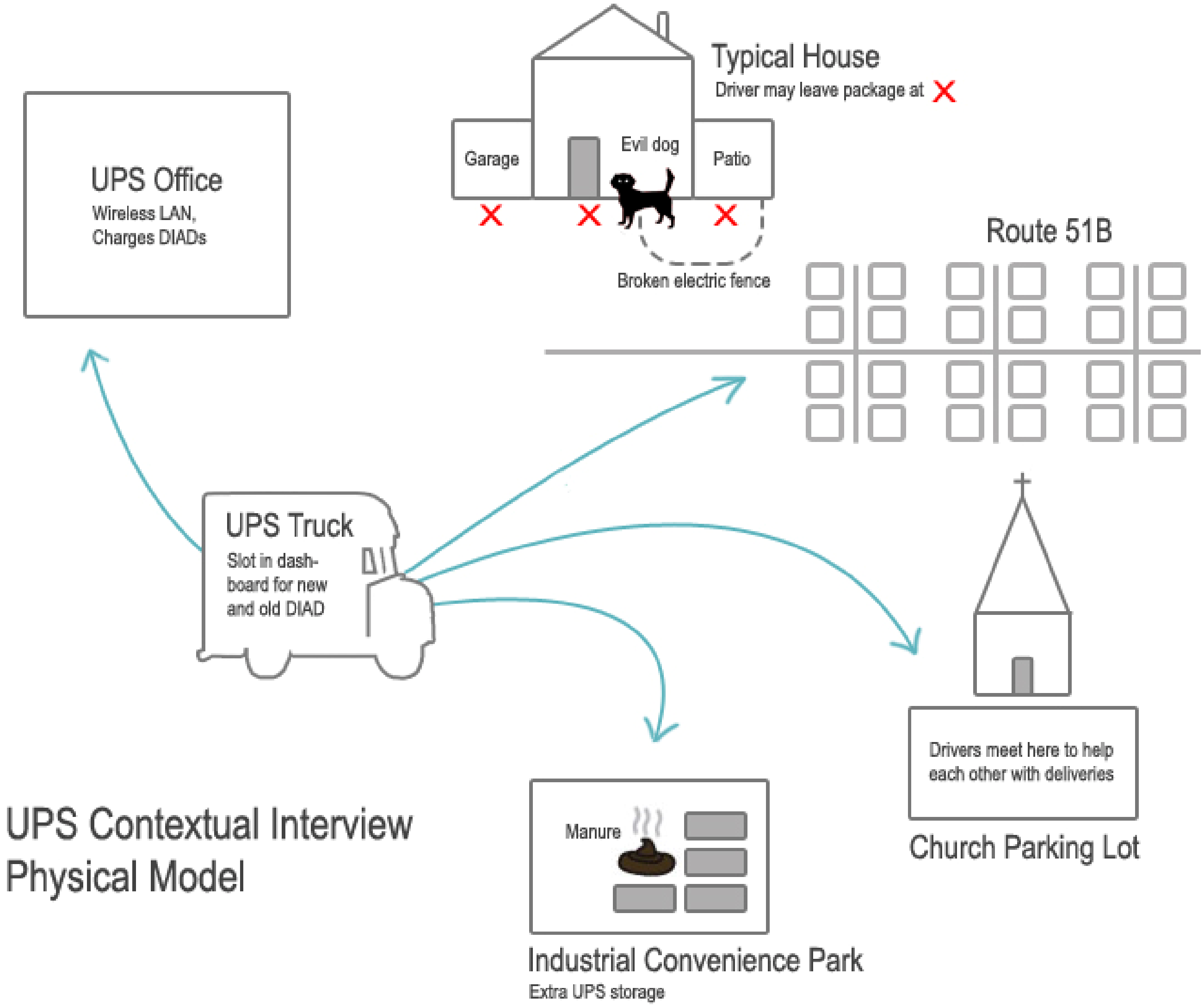
Our UPS Workflow model is from the perspective of Bob, a UPS driver. Bob makes deliveries and picks up packages along a given route. He uses a handheld device made by Symbol to scan packages. Generally, Bob is happy with his durable handheld device. He types packages into it manually and can have customers sign it for a package. The only problems Bob has with his device are that if it breaks, he must manually enter data on paper. Also, the device has no system in place for proving delivery by methods such as photography, which Bob has had to do with his mobile phone. He supervisors at headquarters monitor Bob's delivery and sometimes send him text messages. These can be useful, such as information about a route, or they can be useless and annoying, such as asking Bob when he will be done with his route (he claims he has no way of knowing). If one of the UPS drivers is overworked, he calls another driver and they meet in a church parking lot to share the delivery load.

UPS Cultural Model:



Bob has a strained relationship with his supervisors in management. He believes the policies they create are anal, for instance forcing long explanations of why packages aren't delivered. Also, Bob receives text messages from supervisors throughout the day the he mostly believes are superfluous and annoying. However, Bob has to reply and be police, as drivers that do not are fired. Bob believes the union protects the workers and can get a job back for a worker if they are fired unfairly. During the busy holiday season, Bob is helped by a helper who is given an inferior handheld device by management. Bob's other frustration are the customers who sometimes try to steal packages at the driver's expense.

UPS Physical Model:



UPS Artifact Models

These are photographs of a DIAD, or Delivery Information Acquisition Device, designed by Symbol for UPS deliveryman. We would later on use a much smaller but similarly durable Symbol MC70 for much of our prototyping.

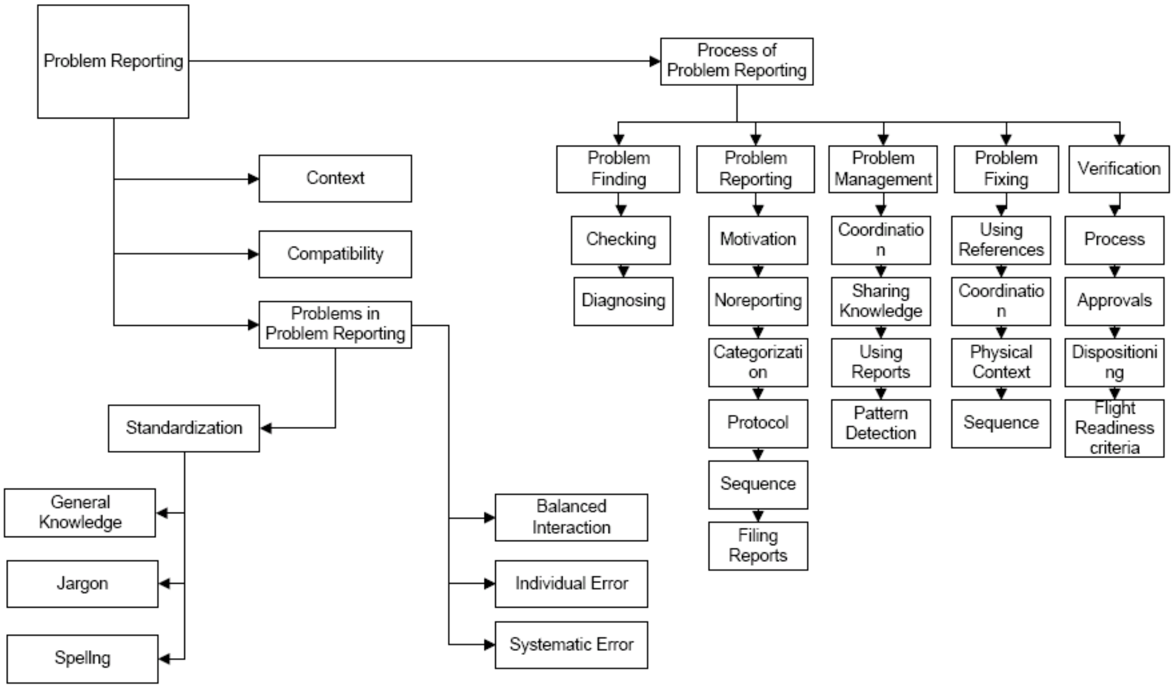
Like the MC70, the DIAD is “hardened” and very durable, designed to tolerate an extensive amount of abuse and weathering. Its purpose is to log the delivery of bar-coded packages to people’s doorsteps and current inventory.

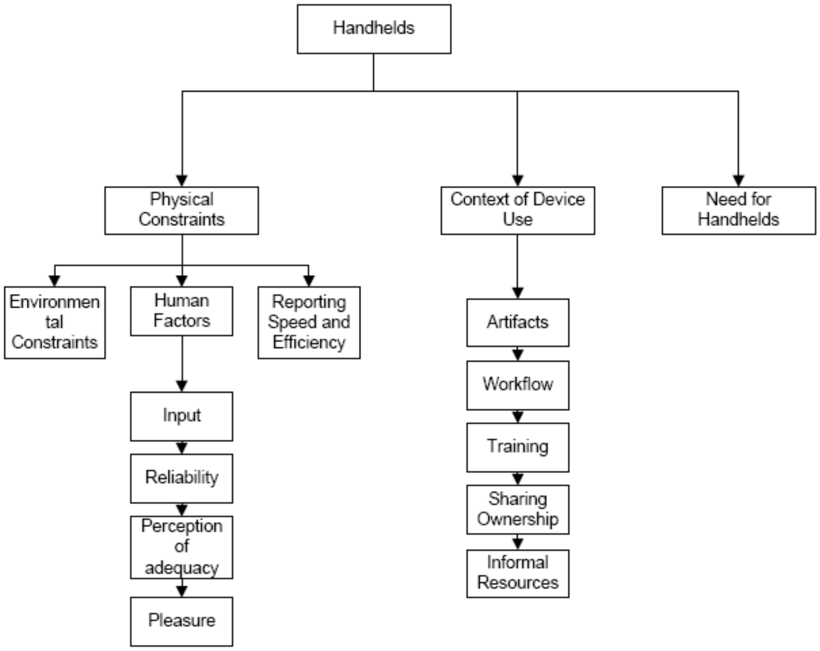
It’s relatively large and designed to be left in a slot on the dashboard of UPS trucks, or left on a shelf. Navigation and bar code reader activation buttons are duplicated on the left and right sides for use by either hand, as the deliveryman juggles boxes. The device can survive rain and snow, and rarely runs out of battery life during a working shift.

When the recipient of a package signs on the touch screen, the lettering on the screen flips to allow the user to hold the device with the controls towards himself or herself during signing. A special stylus is not needed for use of the touchscreen.

In addition to GPS, the device allows connections through infrared, wireless networking, CDMA, Bluetooth, and an acoustical modem (if a phone is laid vertically across its lower right side). These connections are used for a variety of purposes, mainly the transfer of inventory information, real-time logging of package transfers, and sending and receiving of notifications between the deliveryman and supervisors at the office.

Second Iteration of Focus-Setting





This second iteration of focus-setting was performed by the three team members en route to KSC based on the preparatory contextual models, and guided in the collection of the data that would form the KSC and consolidated models, below.

Kennedy Space Center Contextual Models

The following results were obtained over a two-day period at Kennedy Space Center, during the Spring Break of the Carnegie Mellon Spring 2007 semester, the 14th and 15th of March. They are central to our understanding of problem reporting and resolution. All prior literature reviews and early CIs were aimed at properly preparing for this event, and the consolidated KSC data was mined and exploited for the remainder of the project.

We interviewed at five different locations at KSC, including participants from three major NASA contractors as well as NASA civil servants.

Payload Depot

This depot, located in the main central area of KSC, is a high-quality machine shop specializing in custom parts that have never been made before and will never be made again, frequently for installation in the ISS modules. We received a demonstration of another of their creations, the new eWAD system, or Electronic Work Authorization Document system, an online work ordering system that replaced the older paper system.

We quickly realized that WADs were different from problem reports or PRs, and therefore out of our scope, yet at the same time WADs are central to the work of technicians all over NASA. The ideal solution must incorporate WADs in some form.

International Space Station (ISS)

The modules of the space station are carefully assembled in a staging area used by the technicians of several different nations. In practice the multinational groups do not collaborate, and so significant intercultural boundaries are not part of our user base. The American modules are assembled by Boeing personnel.

Although managerial personnel were present during this CI, by leaving one investigator with them, we were able to get a valuable source, the local technical lead, alone and free to speak. This participant had built himself a problem reporting program with Visual Basic, and used it to communicate problem reports to the local Quality, who would either bounce it back if it was incomplete or incorrect, or forward it on to Engineering. It was here that we learned of the two-step process of problem reporting, wherein a nonconformance report is submitted to Quality, vetted, and then submitted as a PR.

We were also able to interview two Boeing engineers involved in the design of the ISS, one with a past as a technician. Although educational, this interview wasn’t as valuable due to being out of the scope of their work, and also out of our scope, as the engineers were not our users. However, the basis for the engineer’s role was ultimately useful information. We would eventually go on to create an interface for engineers. (35)

Lockheed Martin Atlas (LM)

This inquiry was unfortunately a demonstration by a nontechnical manager of problem reporting equipment he couldn’t successfully use. As a result it was of limited value, but did communicate the values of the management. Being responsible for the outcome of the work yet at the same time distant from it, they desire strong powers of oversight and prize any form of blanket cost savings in terms of staff hours.

Vehicle Assembly Building (VAB)

The massive VAB is the staging area where the space shuttle and booster rockets are hoisted onto the external fuel tank before being moved to the launch pad. Although the space shuttle was originally intended to be launched during our trip, the launch was cancelled and the shuttle was returned to the VAB due to hail damage to the external fuel tank. This allowed us to observe during a period of active problem resolution.

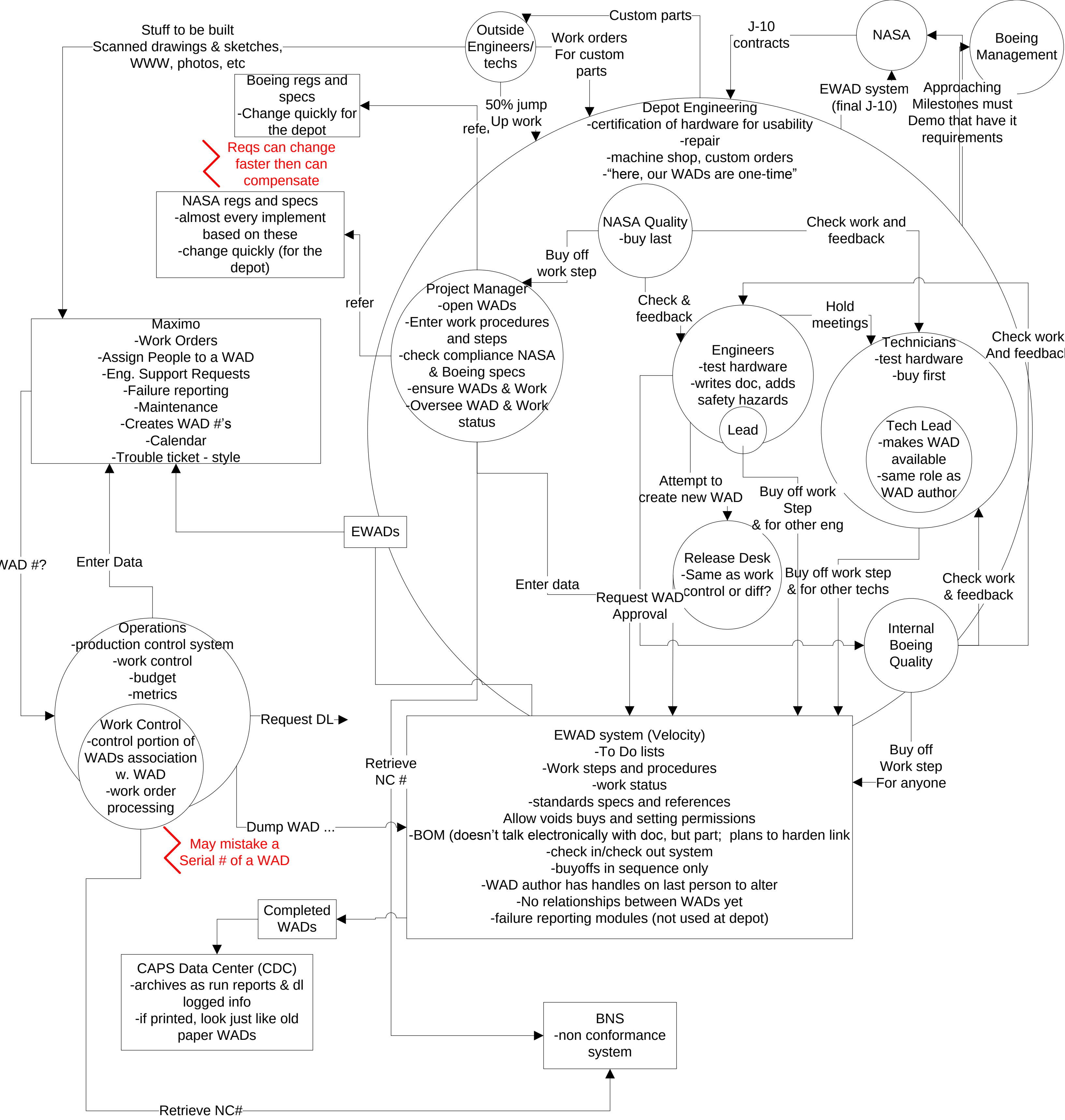
We first visited a Test Assembly Inspection Record (TAIR) station, the USA problem reporting system, which is entirely composed of paper, including a librarian. Here we learned that technicians write their reports on a computer, print them out, and file them in the TAIR library as paper; after the shuttle has launched, these are all scanned as minimally searchable images and placed in a database. As a result, problem reports are least accessible when they are most valuable, and the entire process is extremely slow.

Afterwards, during a tour of the VAB facility and environment, we coincidentally met with a pair of technicians inspecting hail damage at the cap of the external fuel tank, and asked them some questions about the culture of the NASA technical environment.

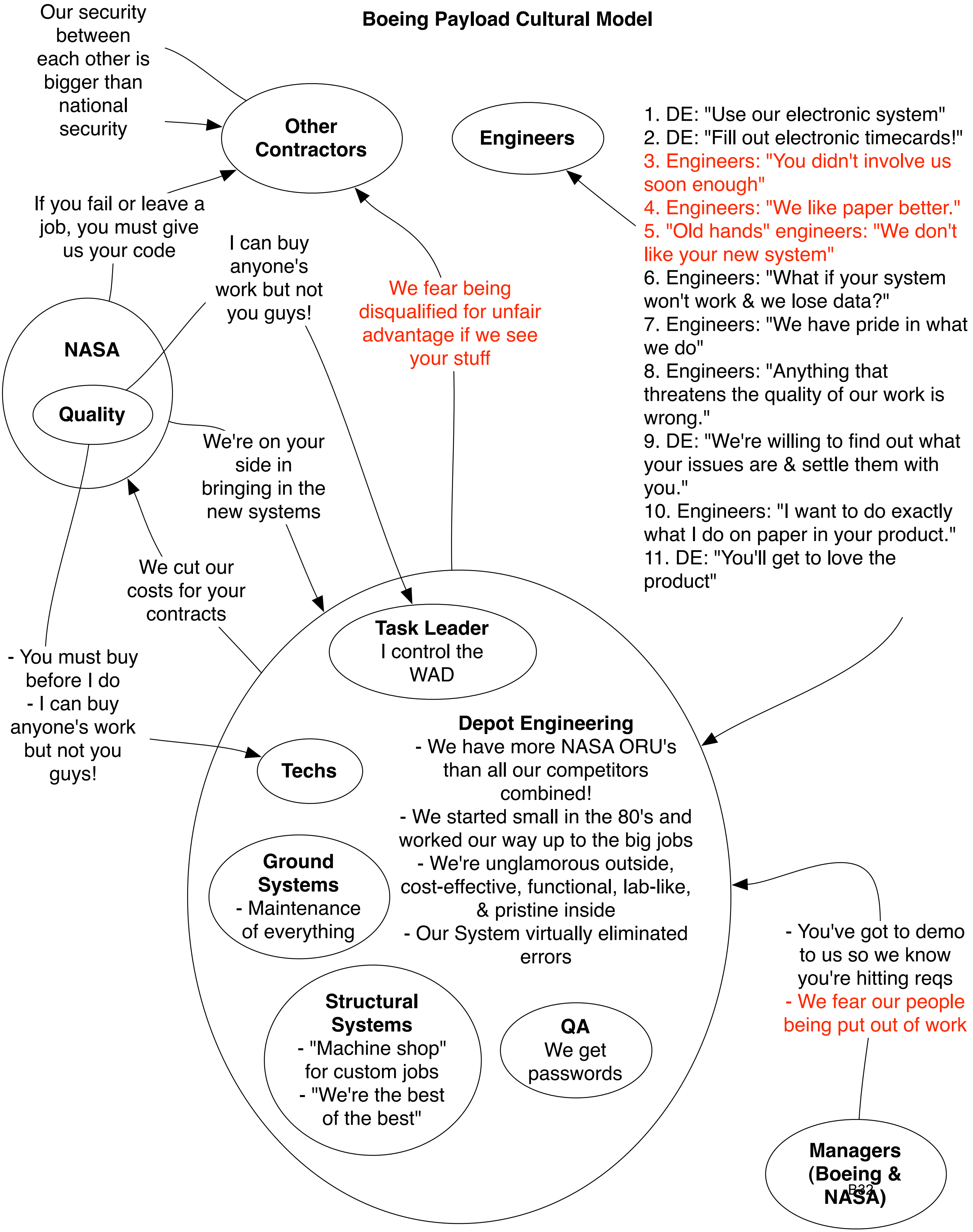
Orbital Processing Facility (OPF)

After return from flight, shuttles experience a great deal of degradation, and require refit. USA’s Orbital Processing Facility is a facility dedicated to total space shuttle overhaul. Here, every part of the space shuttle is checked and many parts replaced.

We encountered a variety of staff checking various parts of the shuttle, and had a particularly large amount of access to those technicians and quality personnel checking the replacement of heat shield tiles along the surface of the shuttle. The problems reported in this activity were different than those of the ISS; whereas ISS problems tend to involve custom components and unusual situations, damaged tile reports come in long series of duplicates, to the point where Quality staff copy and paste older reports, saving time, but risking that some field entries won’t be changed from the older forms.


Stuff to be built
Scanned drawings & sketches,
WWW, photos, etc
Outside Engineers/ techs
Custom parts
Work orders For custom parts
J-10 contracts
NASA
Boeing Management
Boeing regs and specs
-Change quickly for the depot
50% jump Up work
refer
EWAD system (final J-10)
Approaching Milestones must Demo that have it requirements
Depot Engineering
-certification of hardware for usability
-repair
-machine shop, custom orders
-"here, our WADs are one-time"
Reqs can change faster then can compensate
NASA regs and specs
-almost every implement based on these
-change quickly (for the depot)
NASA Quality
-buy last
Check work and feedback
Buy off work step
refer
Project Manager
-open WADs
-Enter work procedures and steps
-check compliance NASA & Boeing specs
-ensure WADs & Work
-Oversee WAD & Work status
Check & feedback
Hold meetings
Maximo
-Work Orders
-Assign People to a WAD
-Eng. Support Requests
-Failure reporting
-Maintenance
-Creates WAD #'s
-Calendar
-Trouble ticket - style
Engineers
-test hardware
-writes doc, adds safety hazards
Lead
Technicians
-test hardware
-buy first
Tech Lead
-makes WAD available
-same role as WAD author
Check work And feedbac
Attempt to create new WAD
Buy off work Step & for other eng
EWADs
WAD #?
Enter Data
Release Desk
-Same as work control or diff?
Enter data
Request WAD Approval
Buy off work step & for other techs
Check work & feedback
Internal Boeing Quality
Operations
-production control system
-work control
-budget
-metrics
Work Control
-control portion of WADs association w. WAD
-work order processing
Request DL
Retrieve NC #
EWAD system (Velocity)
-To Do lists
-Work steps and procedures
-work status
-standards specs and references
Allow voids buys and setting permissions
-BOM (doesn't talk electronically with doc, but part; plans to harden link
-check in/check out system
-buyoffs in sequence only
-WAD author has handles on last person to alter
-No relationships between WADs yet
-failure reporting modules (not used at depot)
Buy off Work step For anyone
Dump WAD ...
May mistake a Serial # of a WAD
Completed WADs
CAPS Data Center (CDC)
-archives as run reports & dl logged info
-if printed, look just like old paper WADs
BNS
-non conformance system
Retrieve NC#

Boeing Payload Cultural Model



Other Contractors

Our security between each other is bigger than national security

If you fail or leave a job, you must give us your code

We fear being disqualified for unfair advantage if we see your stuff

Engineers

1. DE: "Use our electronic system"
2. DE: "Fill out electronic timecards!"
3. Engineers: "You didn't involve us soon enough"
4. Engineers: "We like paper better."
5. "Old hands" engineers: "We don't like your new system"
6. Engineers: "What if your system won't work & we lose data?"
7. Engineers: "We have pride in what we do"
8. Engineers: "Anything that threatens the quality of our work is wrong."
9. DE: "We're willing to find out what your issues are & settle them with you."
10. Engineers: "I want to do exactly what I do on paper in your product."
11. DE: "You'll get to love the product"

NASA

Quality

I can buy anyone's work but not you guys!

We're on your side in bringing in the new systems

We cut our costs for your contracts

- You must buy before I do
- I can buy anyone's work but not you guys!

Task Leader
I control the WAD

Depot Engineering
- We have more NASA ORU's than all our competitors combined!
- We started small in the 80's and worked our way up to the big jobs
- We're unglamorous outside, cost-effective, functional, lab-like, & pristine inside
- Our System virtually eliminated errors

Techs

Ground Systems
- Maintenance of everything

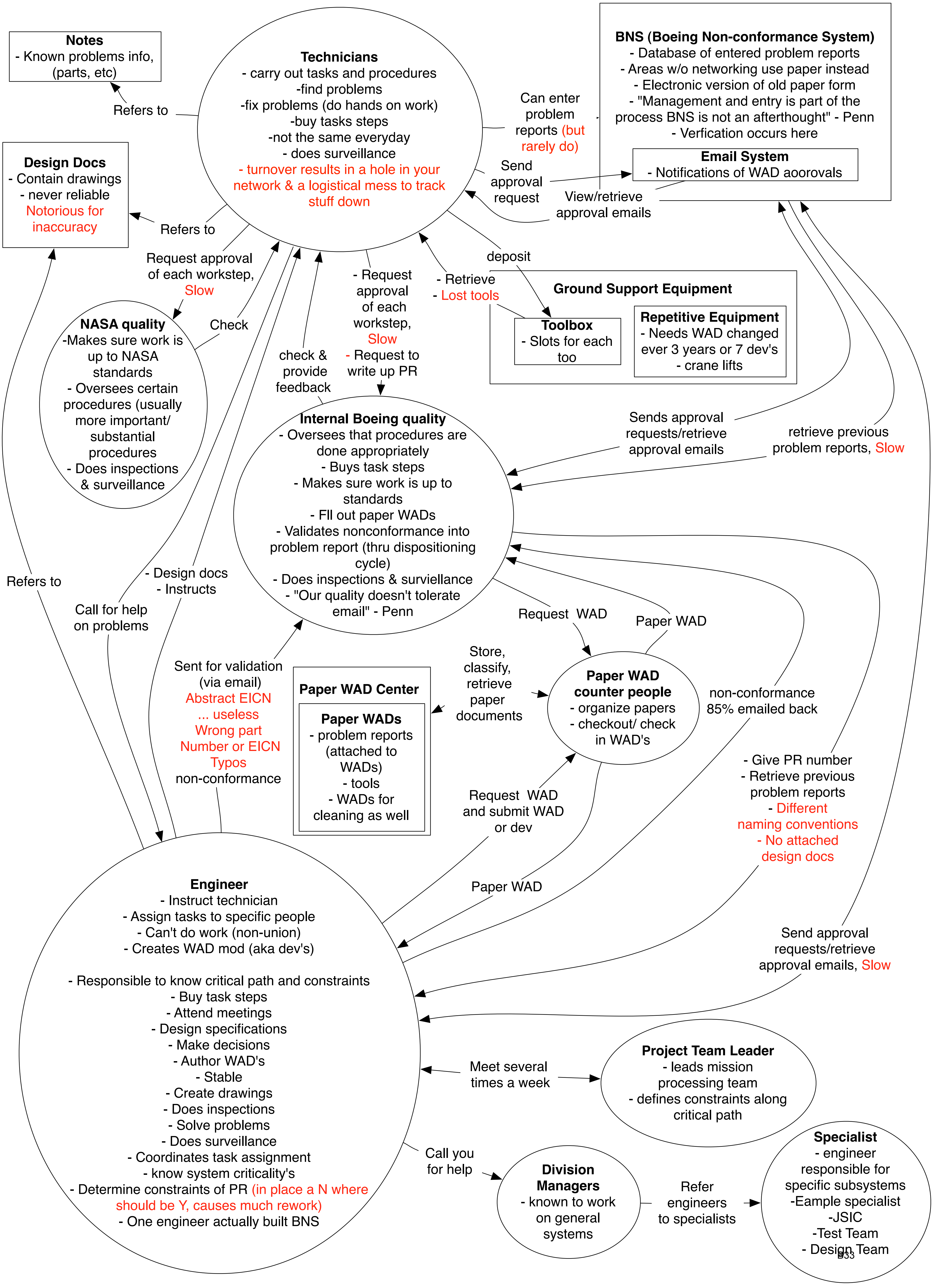
Structural Systems
- "Machine shop" for custom jobs
- "We're the best of the best"

QA
We get passwords

- You've got to demo to us so we know you're hitting reqs
- We fear our people being put out of work

Managers (Boeing & NASA)

Boeing ISS - Workflow



Notes
- Known problems info, (parts, etc)

Refers to

Technicians
- carry out tasks and procedures
-find problems
-fix problems (do hands on work)
-buy tasks steps
-not the same everyday
- does surveillance
- turnover results in a hole in your network & a logistical mess to track stuff down

BNS (Boeing Non-conformance System)
- Database of entered problem reports
- Areas w/o networking use paper instead
- Electronic version of old paper form
- "Management and entry is part of the process BNS is not an afterthought" - Penn
- Verfication occurs here

Email System
- Notifications of WAD aoorovals

Can enter problem reports (but rarely do)

Send approval request

View/retrieve approval emails

Design Docs
- Contain drawings
- never reliable
Notorious for inaccuracy

Refers to

Request approval of each workstep, Slow

Check

- Request approval of each workstep, Slow
- Request to write up PR

check & provide feedback

- Retrieve
- Lost tools

deposit

Ground Support Equipment

Toolbox
- Slots for each too

Repetitive Equipment
- Needs WAD changed ever 3 years or 7 dev's
- crane lifts

NASA quality
-Makes sure work is up to NASA standards
- Oversees certain procedures (usually more important/ substantial procedures
- Does inspections & surveillance

Internal Boeing quality
- Oversees that procedures are done appropriately
- Buys task steps
- Makes sure work is up to standards
- Fll out paper WADs
- Validates nonconformance into problem report (thru dispositioning cycle)
- Does inspections & surviellance
- "Our quality doesn't tolerate email" - Penn

Sends approval requests/retrieve approval emails

retrieve previous problem reports, Slow

Refers to

- Design docs
- Instructs

Call for help on problems

Sent for validation (via email)
Abstract EICN ... useless
Wrong part Number or EICN
Typos
non-conformance

Paper WAD Center

Paper WADs
- problem reports (attached to WADs)
- tools
- WADs for cleaning as well

Store, classify, retrieve paper documents

Request WAD

Paper WAD

Paper WAD counter people
- organize papers
- checkout/ check in WAD's

non-conformance 85% emailed back

Request WAD and submit WAD or dev

Paper WAD

- Give PR number
- Retrieve previous problem reports
- Different naming conventions
- No attached design docs

Send approval requests/retrieve approval emails, Slow

Engineer
- Instruct technician
- Assign tasks to specific people
- Can't do work (non-union)
- Creates WAD mod (aka dev's)

- Responsible to know critical path and constraints
- Buy task steps
- Attend meetings
- Design specifications
- Make decisions
- Author WAD's
- Stable
- Create drawings
- Does inspections
- Solve problems
- Does surveillance
- Coordinates task assignment
- know system criticality's
- Determine constraints of PR (in place a N where should be Y, causes much rework)
- One engineer actually built BNS

Meet several times a week

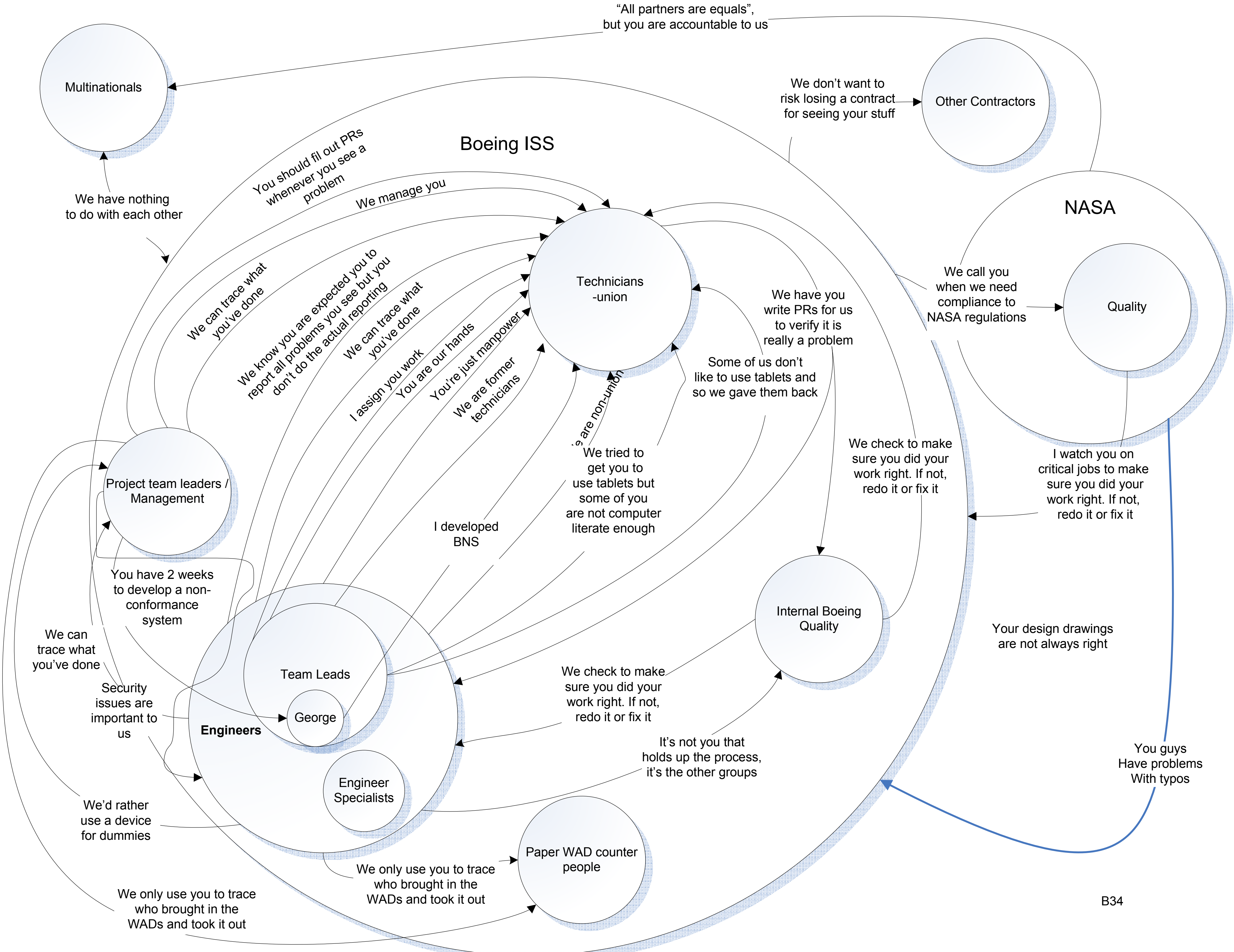
Project Team Leader
- leads mission processing team
- defines constraints along critical path

Call you for help

Division Managers
- known to work on general systems

Refer engineers to specialists

Specialist
- engineer responsible for specific subsystems
-Eample specialist
-JSIC
-Test Team
- Design Team


"All partners are equals",
but you are accountable to us
Multinationals
We have nothing
to do with each other
Other Contractors
We don't want to
risk losing a contract
for seeing your stuff
Boeing ISS
NASA
Quality
We call you
when we need
compliance to
NASA regulations
You should fil out PRs
whenever you see a
problem
We manage you
Technicians
-union
We can trace what
you've done
We know you are expected you to
report all problems you see but you
don't do the actual reporting
We can trace what
you've done
I assign you work
You are our hands
You're just manpower
We are former
technicians
e are non-union
We have you
write PRs for us
to verify it is
really a problem
Some of us don't
like to use tablets and
so we gave them back
We tried to
get you to
use tablets but
some of you
are not computer
literate enough
I developed
BNS
We check to make
sure you did your
work right. If not,
redo it or fix it
I watch you on
critical jobs to make
sure you did your
work right. If not,
redo it or fix it
Project team leaders /
Management
You have 2 weeks
to develop a non-
conformance
system
We can
trace what
you've done
Security
issues are
important to
us
Team Leads
George
Engineers
Engineer
Specialists
Internal Boeing
Quality
We check to make
sure you did your
work right. If not,
redo it or fix it
It's not you that
holds up the process,
it's the other groups
Your design drawings
are not always right
You guys
Have problems
With typos
We'd rather
use a device
for dummies
Paper WAD counter
people
We only use you to trace
who brought in the
WADs and took it out
We only use you to trace
who brought in the
WADs and took it out

B34

Technicians work WADs

Technicians find discrepancy

Technicians call tech lead over

Tech lead examines discrepancy with technicians

Tech lead goes to computer

Tech lead enters discrepancy data into BNS
--> Warning: he made it
--> Typos are a problem

IPR, PR, or DR

H/S/U

DD250 Y/N/U
--> constraints?
--> crit code? CIL = critical incident list

Detected During: DOC, RCV, SHIP, SURV, XDOC, XFER

Work Area

Shop #

EICN
--> often in wrong EICN
--> larger-scope EICNs are useless

Part #s
--> often in wrong part #

Part Name (autofills)

Serial # for design docs

Quantity

Vendor

Payload

Auto STS / Eff

Emails to QE

QE checks

QE decides to validate or send back

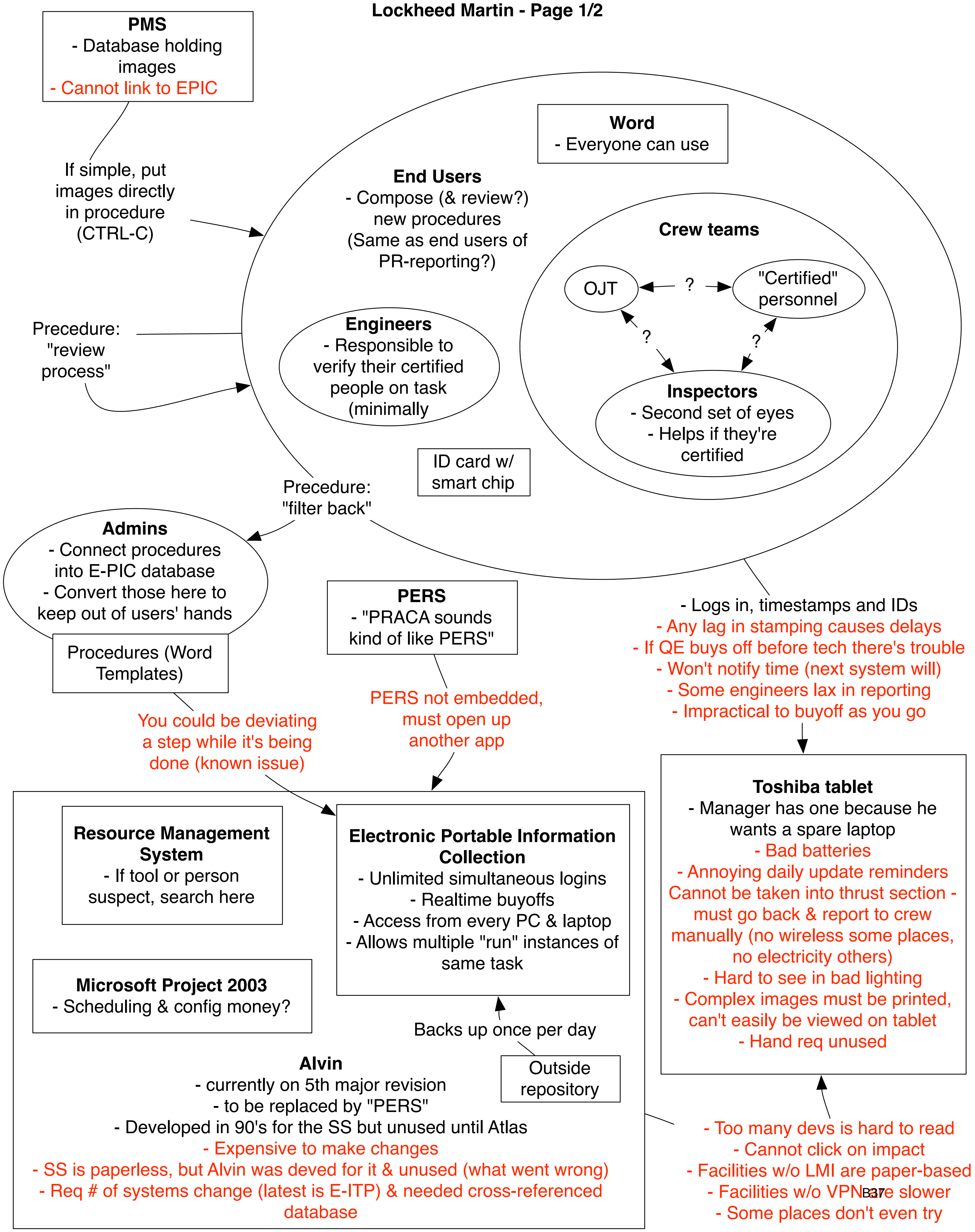
QE assigns number

Future WAD generated or deviation created
--> sometimes deviations were wrong and the original way was right

WAD distributed

Technicians work WADs

Lockheed Martin - Page 1/2



PMS
- Database holding images
- Cannot link to EPIC

If simple, put images directly in procedure (CTRL-C)

Word
- Everyone can use

End Users
- Compose (& review?) new procedures
(Same as end users of PR-reporting?)

Crew teams

OJT

?

"Certified" personnel

?

?

Inspectors
- Second set of eyes
- Helps if they're certified

Precedure: "review process"

Engineers
- Responsible to verify their certified people on task (minimally

ID card w/ smart chip

Precedure: "filter back"

Admins
- Connect procedures into E-PIC database
- Convert those here to keep out of users' hands

Procedures (Word Templates)

You could be deviating a step while it's being done (known issue)

PERS
- "PRACA sounds kind of like PERS"

PERS not embedded, must open up another app

- Logs in, timestamps and IDs
- Any lag in stamping causes delays
- If QE buys off before tech there's trouble
- Won't notify time (next system will)
- Some engineers lax in reporting
- Impractical to buyoff as you go

Toshiba tablet
- Manager has one because he wants a spare laptop
- Bad batteries
- Annoying daily update reminders
Cannot be taken into thrust section - must go back & report to crew manually (no wireless some places, no electricity others)
- Hard to see in bad lighting
- Complex images must be printed, can't easily be viewed on tablet
- Hand req unused

Resource Management System
- If tool or person suspect, search here

Electronic Portable Information Collection
- Unlimited simultaneous logins
- Realtime buyoffs
- Access from every PC & laptop
- Allows multiple "run" instances of same task

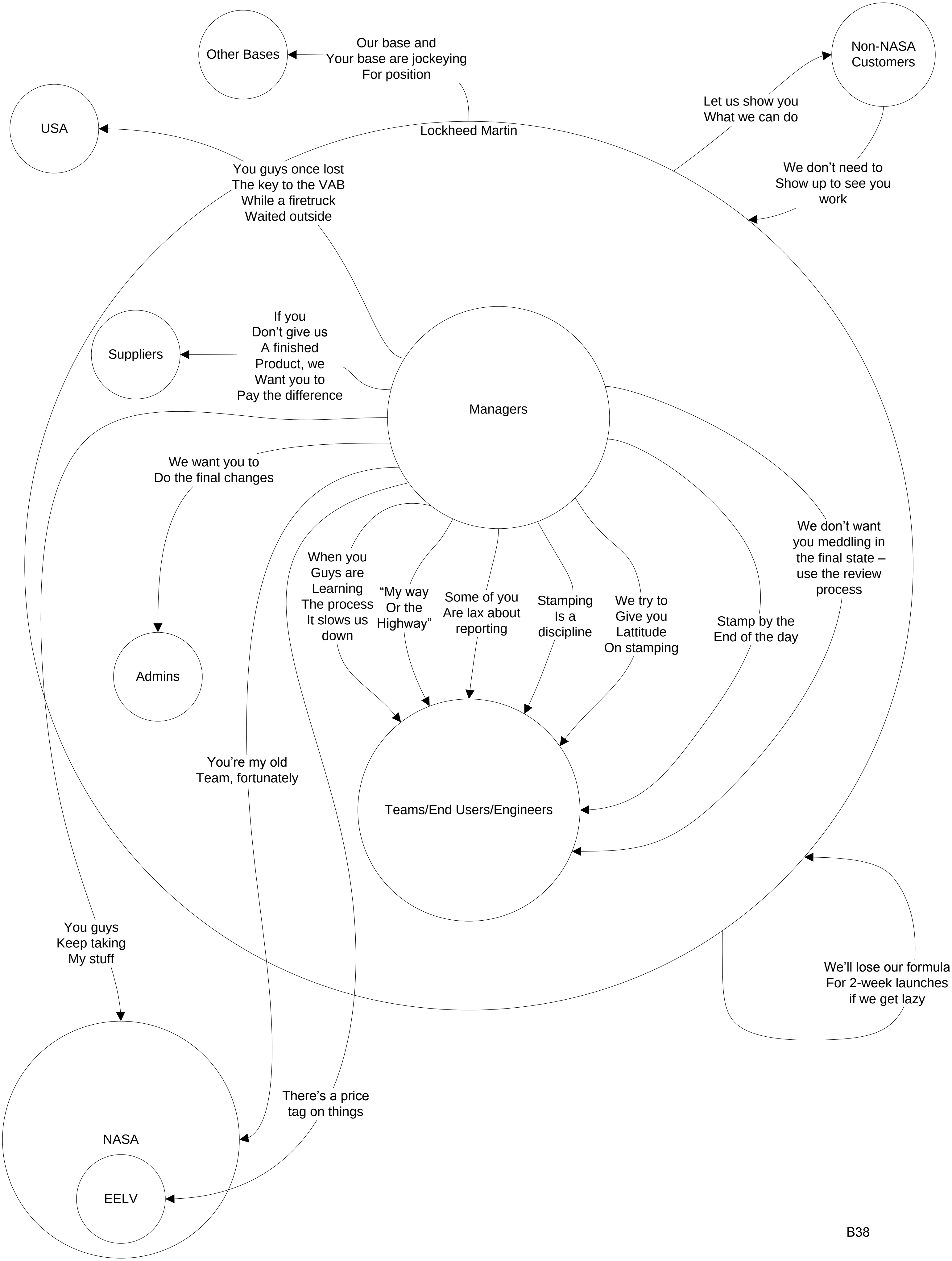
Microsoft Project 2003
- Scheduling & config money?

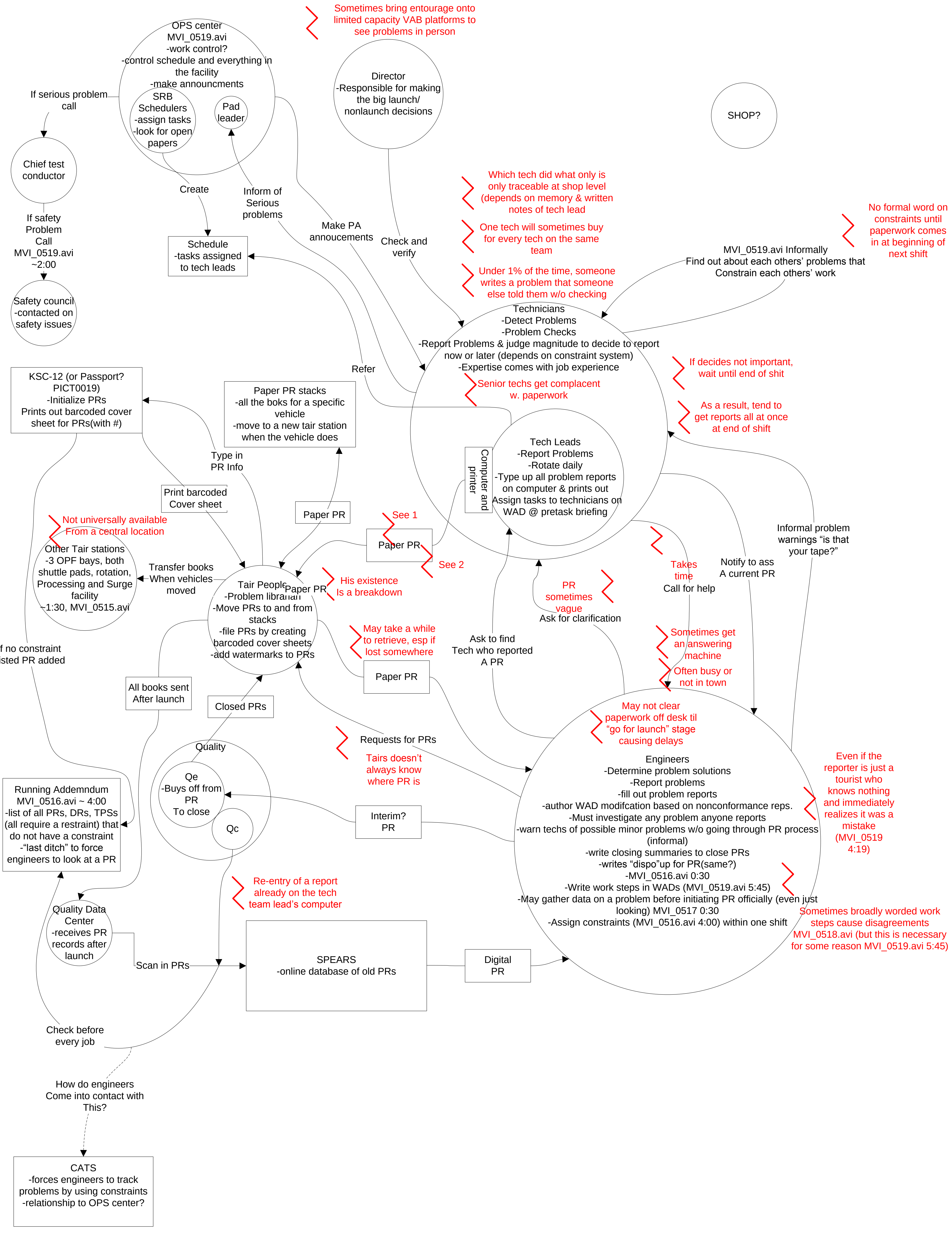
Backs up once per day

Outside repository

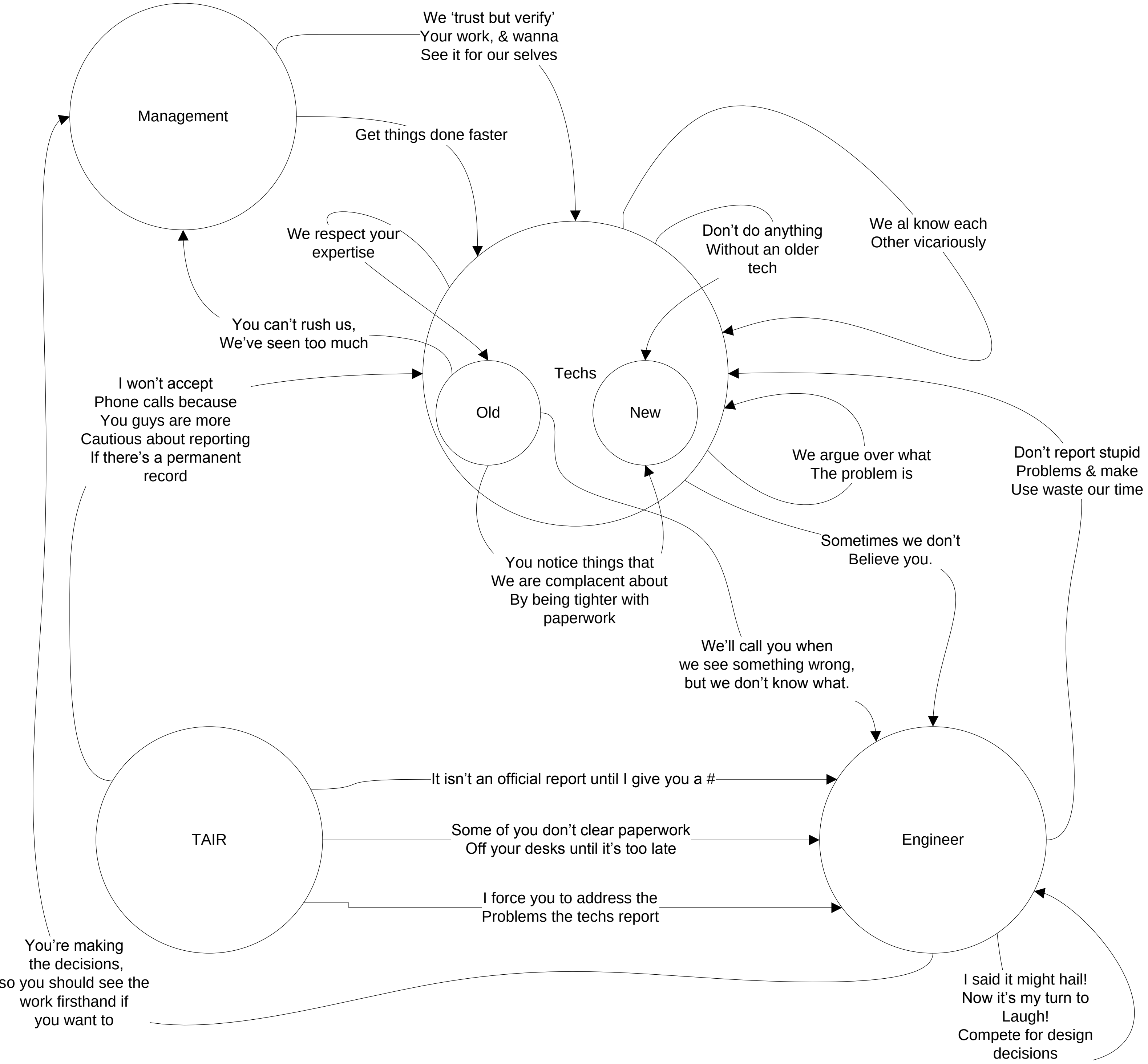
Alvin
- currently on 5th major revision
- to be replaced by "PERS"
- Developed in 90's for the SS but unused until Atlas
- Expensive to make changes
- SS is paperless, but Alvin was deved for it & unused (what went wrong)
- Req # of systems change (latest is E-ITP) & needed cross-referenced database

- Too many devs is hard to read
- Cannot click on impact
- Facilities w/o LMI are paper-based
- Facilities w/o VPN are slower
- Some places don't even try


Other Bases
Our base and Your base are jockeying For position
Non-NASA Customers
USA
Lockheed Martin
Let us show you What we can do
We don’t need to Show up to see you work
You guys once lost The key to the VAB While a firetruck Waited outside
Suppliers
If you Don’t give us A finished Product, we Want you to Pay the difference
Managers
We want you to Do the final changes
Admins
When you Guys are Learning The process It slows us down
“My way Or the Highway”
Some of you Are lax about reporting
Stamping Is a discipline
We try to Give you Lattitude On stamping
Stamp by the End of the day
We don’t want you meddling in the final state – use the review process
Teams/End Users/Engineers
You’re my old Team, fortunately
You guys Keep taking My stuff
We’ll lose our formula For 2-week launches if we get lazy
There’s a price tag on things
NASA
EELV



1 Some image evidence doesn't say how big it is (zooming in on a scratch makes it a canyon)
2 Some PRs are inconsequential


Management
We 'trust but verify'
Your work, & wanna
See it for our selves
Get things done faster
We respect your
expertise
Techs
Old
New
Don't do anything
Without an older
tech
We al know each
Other vicariously
You can't rush us,
We've seen too much
I won't accept
Phone calls because
You guys are more
Cautious about reporting
If there's a permanent
record
We argue over what
The problem is
Don't report stupid
Problems & make
Use waste our time
Sometimes we don't
Believe you.
You notice things that
We are complacent about
By being tighter with
paperwork
We'll call you when
we see something wrong,
but we don't know what.
TAIR
Engineer
It isn't an official report until I give you a #
Some of you don't clear paperwork
Off your desks until it's too late
I force you to address the
Problems the techs report
You're making
the decisions,
so you should see the
work firsthand if
you want to
I said it might hail!
Now it's my turn to
Laugh!
Compete for design
decisions

Sequence of Problem Reporting
Location: VAB
Patrick Malatack
3/27/2007

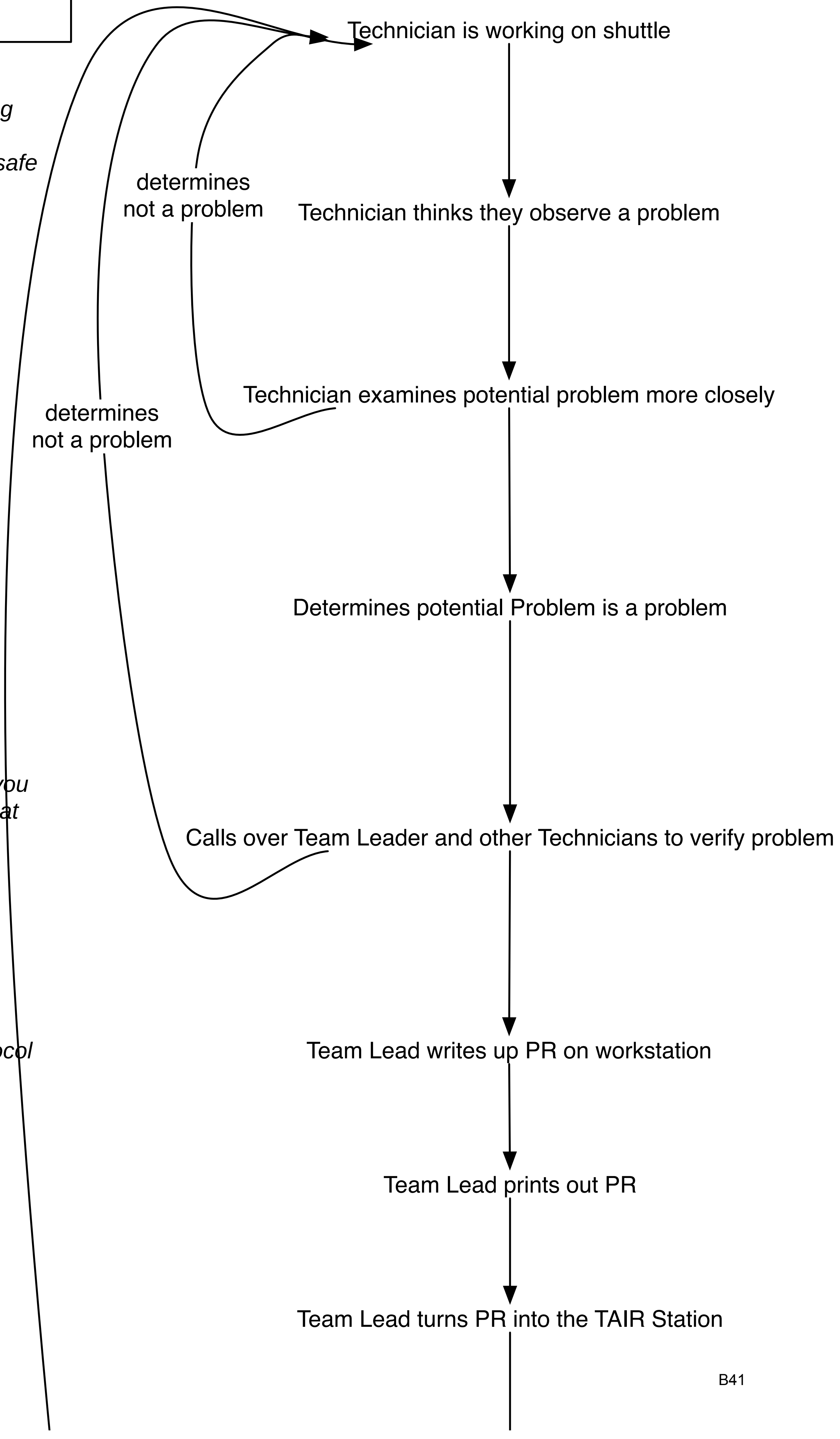
Trigger: *Notice something doesn't feel right*

Intent: *Make shuttle as safe as possible*

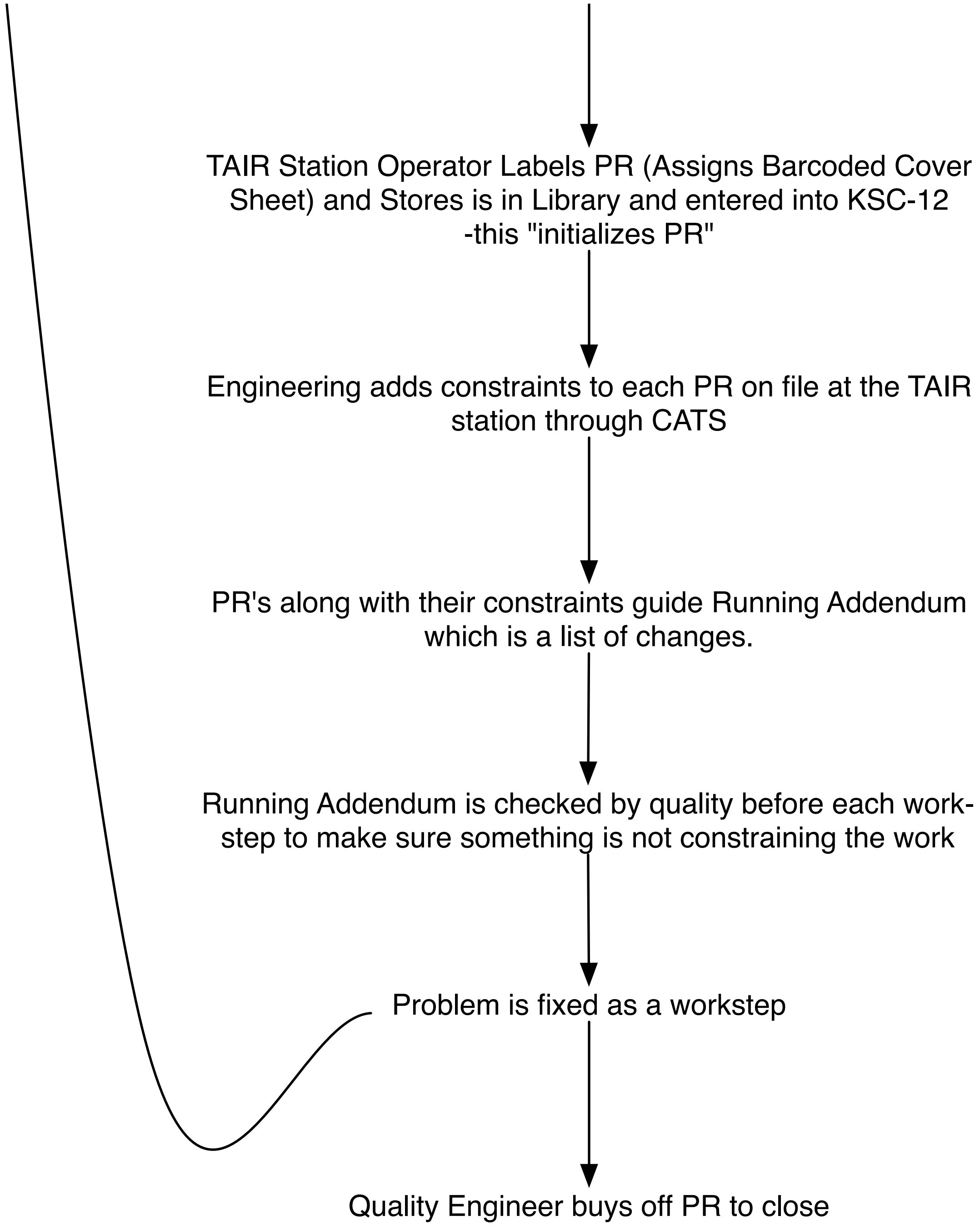
Sub-intent: *Don't miss reporting a problem that exists*

Sub-intent: *Make sure you dont report something that isnt a real problem*

Sub-intent: *Follow protocol for safety*



Sub-intent: *Follow protocol for safety*



TAIR Station Operator Labels PR (Assigns Barcoded Cover Sheet) and Stores is in Library and entered into KSC-12 -this "initializes PR"

Engineering adds constraints to each PR on file at the TAIR station through CATS

PR's along with their constraints guide Running Addendum which is a list of changes.

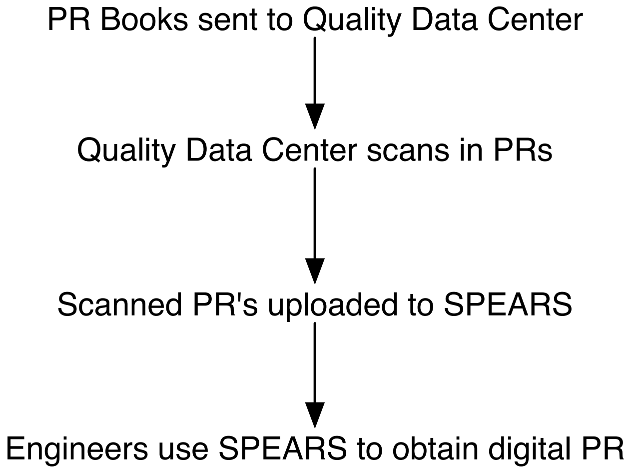
Running Addendum is checked by quality before each work-step to make sure something is not constraining the work

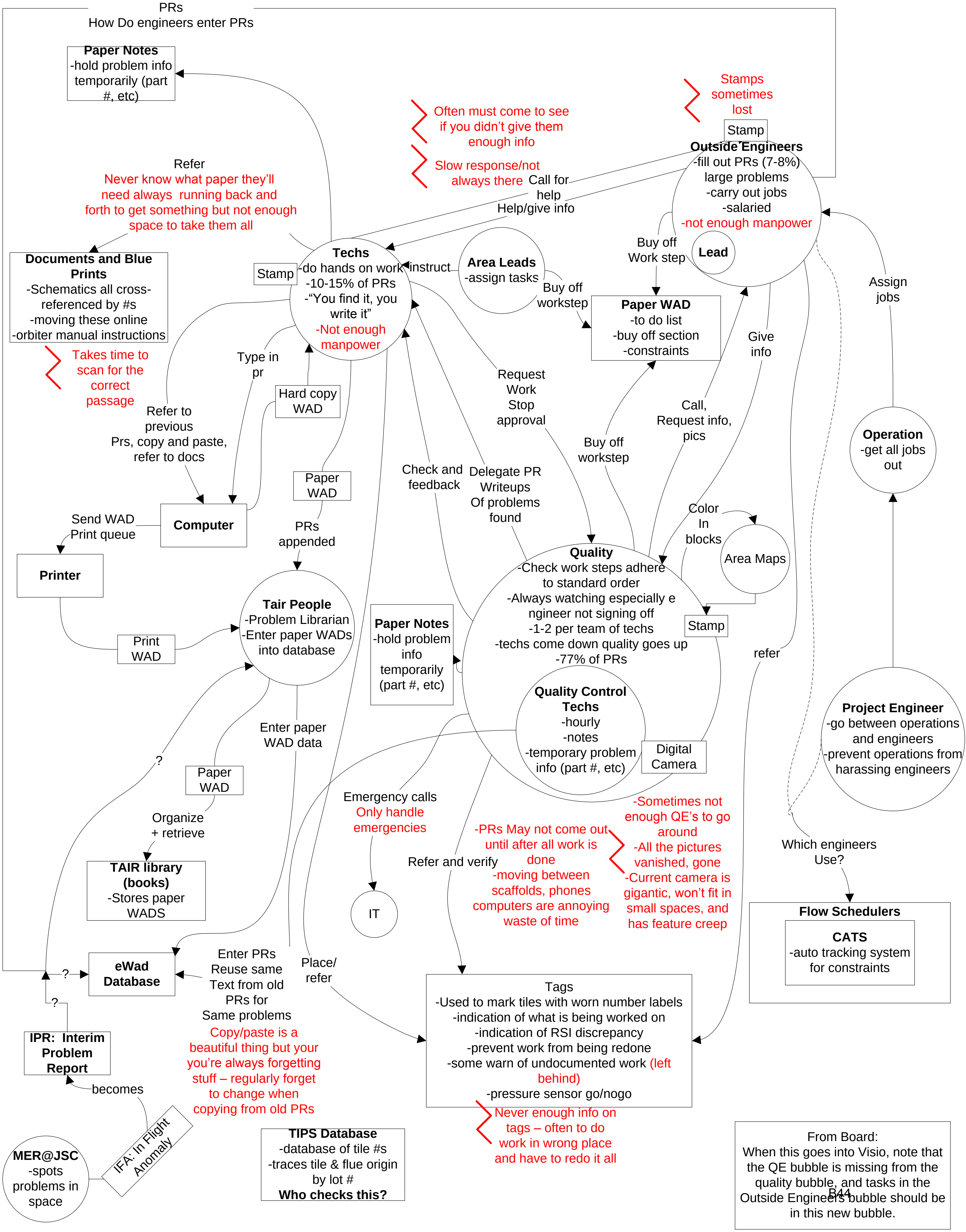
Problem is fixed as a workstep

Quality Engineer buys off PR to close

Trigger: *Shuttle Launched*
Intent: *Explore Space*

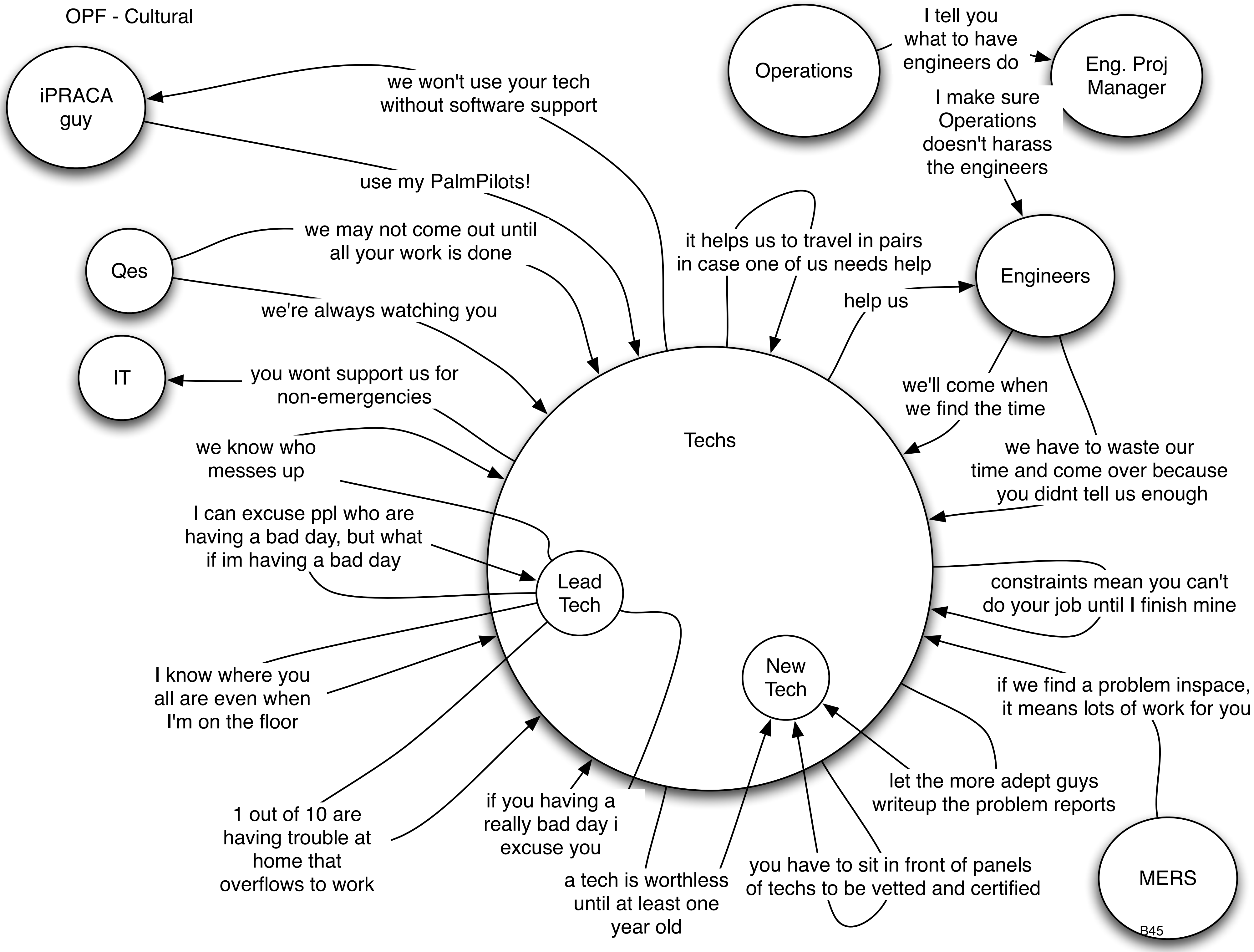
Sub-intent: *Create record that will be useful for future shuttle missions, making it easier and safer to explore space*





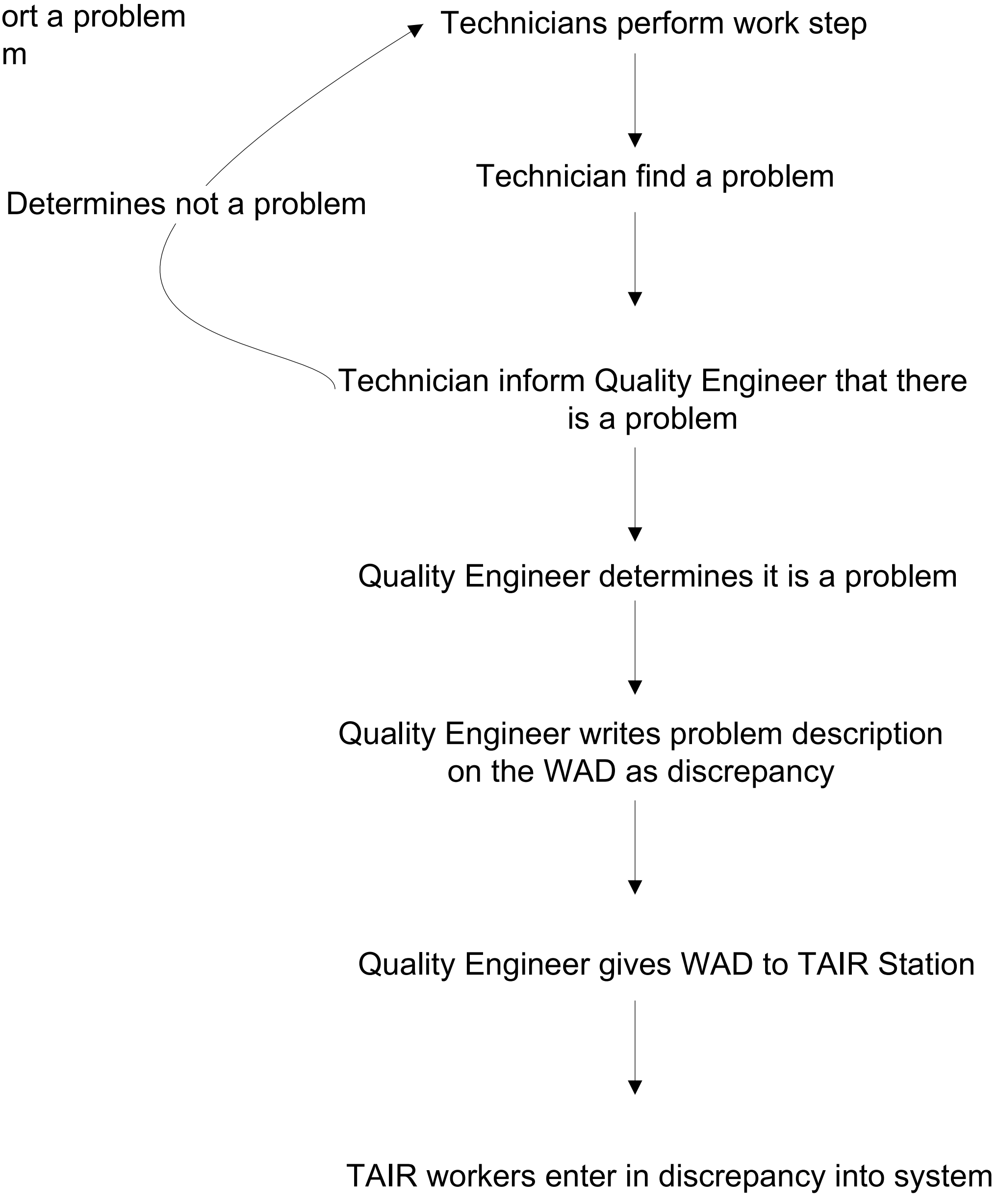
From Board:
When this goes into Visio, note that the QE bubble is missing from the quality bubble, and tasks in the Outside Engineers bubble should be in this new bubble.

OPF - Cultural



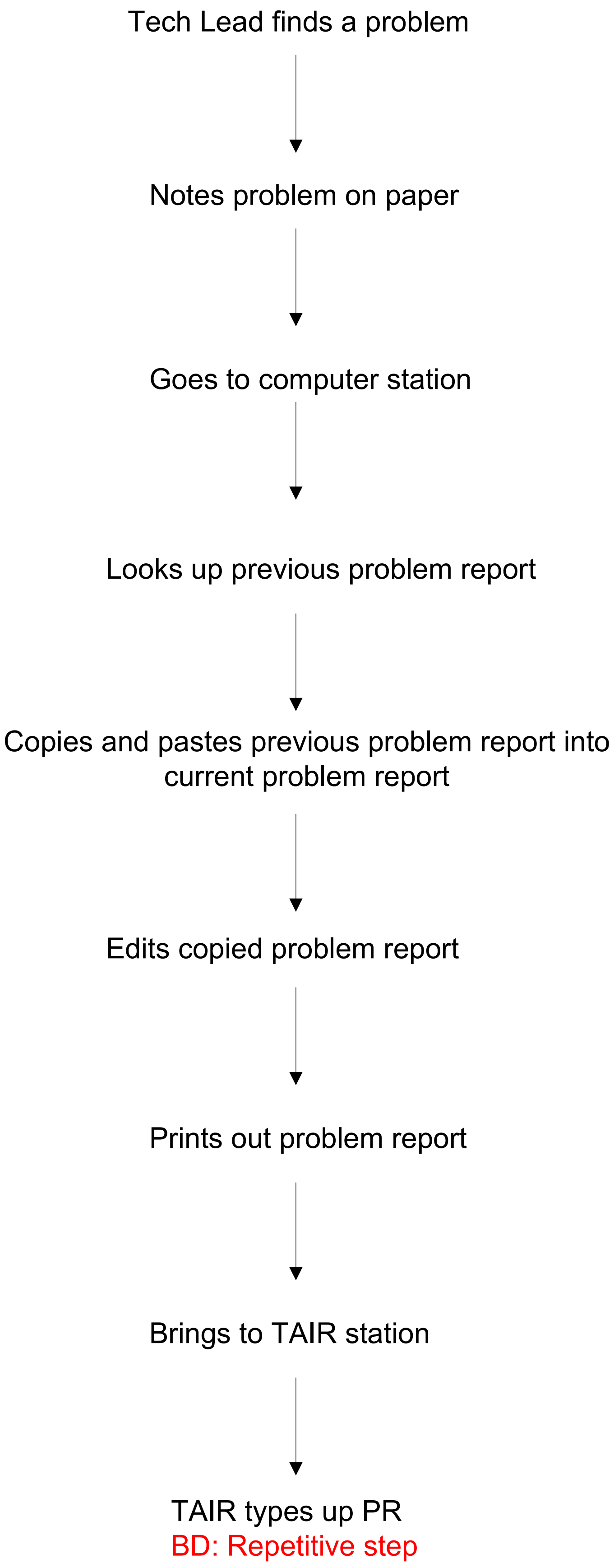
Sequence of Problem Reporting
Location: OPF
Karen Au
4/1/07

Intent: Technicians report a problem
Trigger: Finds a problem



Intent: Tech Lead report a problem
Trigger: Finds a problem

Sub-Intent: Use previous problem report for frequent problems



Tech Lead finds a problem

Notes problem on paper

Goes to computer station

Looks up previous problem report

Copies and pastes previous problem report into current problem report

Edits copied problem report

Prints out problem report

Brings to TAIR station

TAIR types up PR
BD: Repetitive step

Intent: Quality Tech report a problem
Trigger: Finds a problem

Quality Tech finds a problem

Writes down on paper

Gets camera

Takes picture of problem
BD: Camera is clunky and does not always fit in space

Sub-Intent: Get help to identify problem

Sends picture to Engineer

Engineers determine enough information in picture to identify problem
BD: Picture quality does not reflect actual size or not clear enough

Calls engineer to look at problem
BD: Engineers not always there, sometimes wait is overnight

Engineers add constraints
Engineers identify problem and inform Quality Tech

Quality Tech types up problem report, entered into system

Consolidated Contextual Models

After creating the individual contextual models shown above, we went on to create the consolidated models below. These constituted the most intense group activity of the Spring 2007 semester. They are described in the main body of the paper (16) but for purposes of space and simplicity only represented by a simplified “nutshell” workflow diagram. Here, the models are spread out in the full expression of their complexity.

Once complete, these models gave us a common mental structure into which we placed our visions of possible designs. This was vital, particularly because almost half the group never shared the same perspective by experience until the Johnson Space Center trip, late in the lifetime of the project.

Consolidated Workflow Model

This is concerned our most significant model, due to the presence of three critical roles: those of technician, quality person, and engineer. The methods by which these roles communicate about problems is, in theory, the problem reporting system. Unfortunately, currently the typical NASA PR system possesses so many breakdowns that much of the important problem-related communications can be seen to bypass it, reducing the value of the system as an archive – and even that archiving capacity is severely reduced by breakdowns in the methods of storage and retrieval.

Consolidated Cultural Model

Unusual for a cultural model, the main breakdown we must worry about is that of general suspicion of those “technology pushers” who have earned a reputation for promising much and delivering small amounts of unused technology, without technical support. Previous attempts at replacement of the PR system have failed, and for reasons.

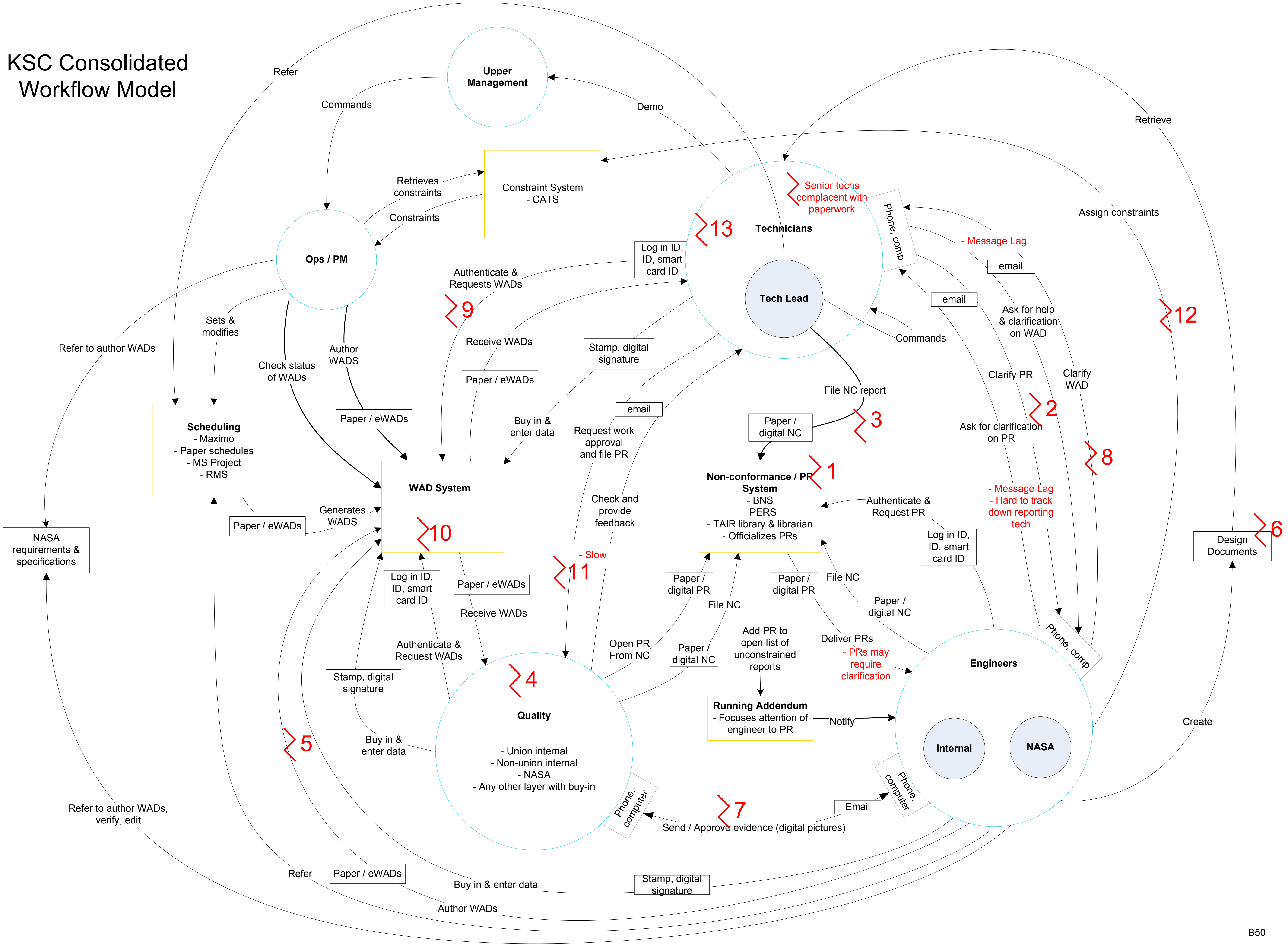
In addition, it’s apparent from this model that every superficial and ambiguous problem report that engineers must spend an inordinate amount of time on leaves a mark. We came to infer that much of the delay in responding to problem reports is due to the suspicion that the PR is simply not worth reading.

Consolidated Sequence Model

The sequence model spreads out many of the breakdowns in data entry engineers and technicians experience across the lifecycle of their submitting of the report. Many of the engineers’ problems are out of our scope, but the need for engineers to find the technicians working on a WAD points us towards recommending a tighter relationship between WAD and PR interfaces in the future.

Typical problem report creation problems relate to difficulties in data entry and collection of multimedia attachments, and typographical errors and inaccuracies stemming from the separation of the reporting workspace from the problem workspace.

KSC Consolidated Workflow Model



Consolidated Workflow Breakdown List

1 PR System
Lost PRs
PRs not centralized
Slow to retrieve
Slow to approve
Necessary documents/images not attached
PRs vague
Vulnerable to typos in serial #s
Difficult terminologies

2 Tech-engineers
Vague PRs
Engineer unavailable to take call
Lag

3 Techs – PR
Inconsequential PRs
Lag
Vague PRs, requiring engineer visit

4 Quality
Tool-camera too bulky, too hi-res, feature creep
Lack of manpower

5 Engineer – WAD
Broadly-worded worksteps

6 Design Documents Database
Can’t take all design docs wherever you want

7 Engineer Quality
Slow to send/respond

8 Engineers-Techs
Tech hard to find or unavailable
lag

9 Techs-WAD
Slow to buy off
One tech will buy for others

10 WAD
No real time updates of deviations
Reporting is a break in the process

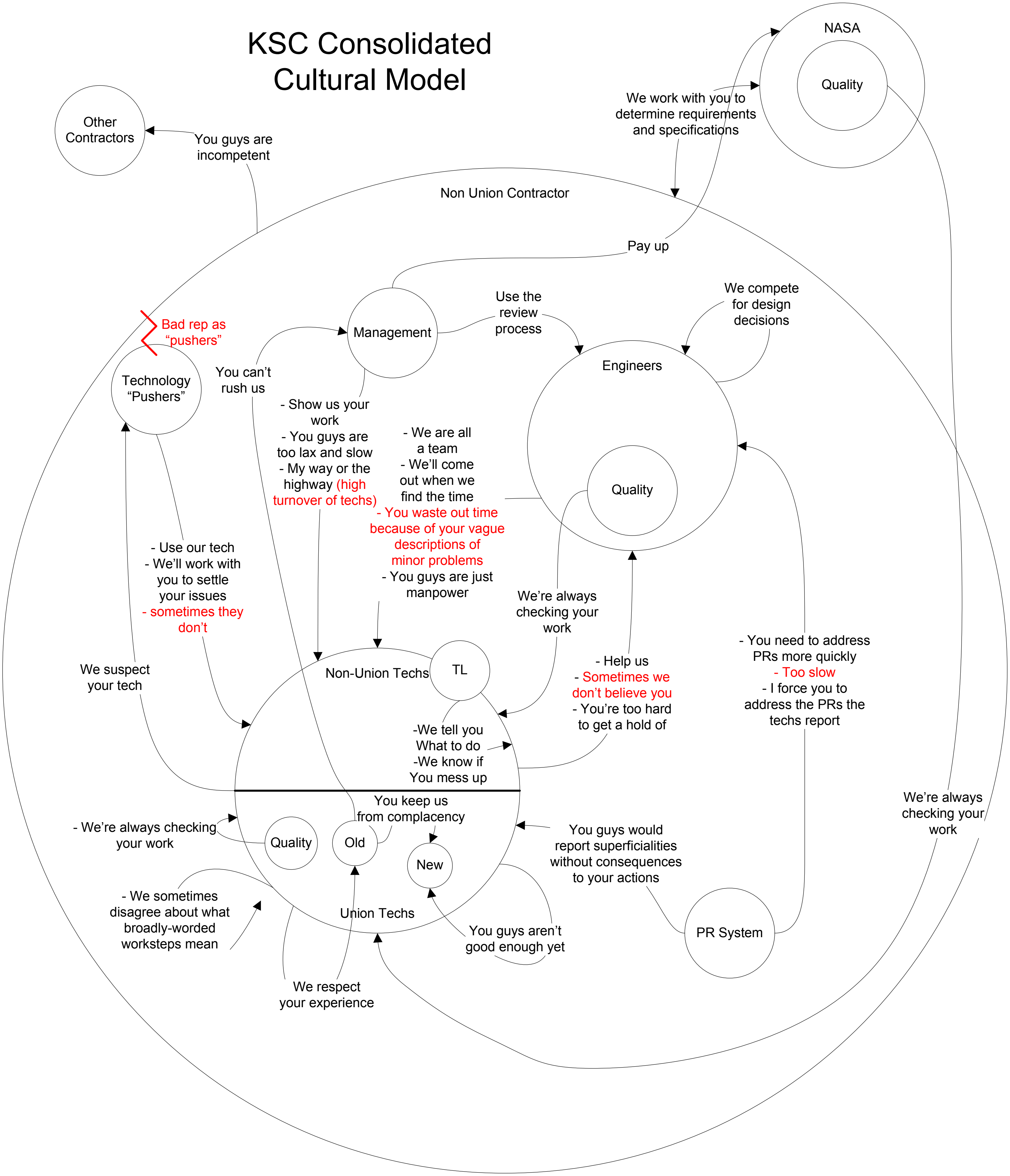
11 Tech-Quality
Slow to request workstep approval

12 Engineers-Constraint System
No incentive to assign constraints
Lag

13 Techs
Turnover leaves hole in information network
Lack of manpower
Disorganized at shop level

14 Senior techs
Complacent with paperwork

KSC Consolidated Cultural Model



Sequence of Problem Reporting
Consolidate Model

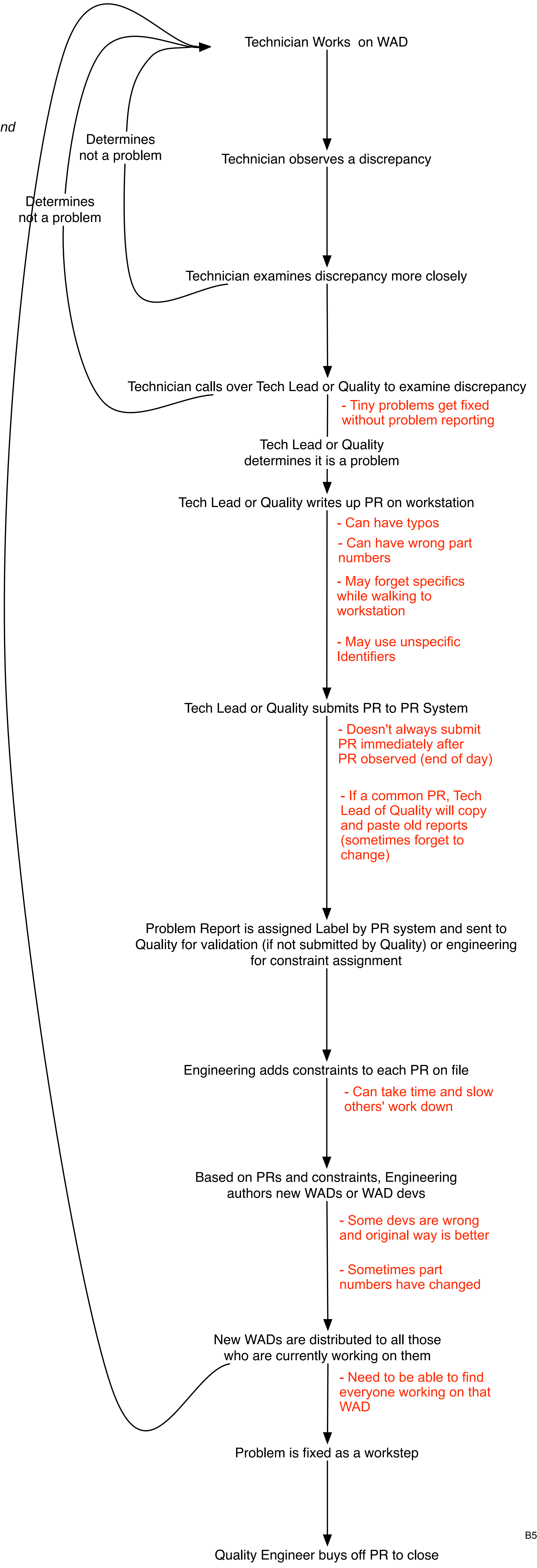
Trigger: *Notice something doesn't feel right*

Intent: *Perform all WADs and report all problems*

Sub-intent: *Don't miss reporting a problem that exists*

Sub-intent: *Make sure you don't report something that isn't a real problem*

Sub-intent: *Follow protocol for safety*



Concept Validation Foci & Provocative Examples

Working within the group, but not expending the same amount of time and effort as normal for an affinity diagram, we grouped all the concepts we were unsure about into singular categories and fanned out across the NASA Ames area. These questions helped give us more assurance of our data, and also get us in contact with possible user testers.

Annotations - How do people write on things, why do they do that, and where do those annotations go?

On the handheld you can take a picture of something broken, and then begin scribbling on it with a stylus on the screen, to point out parts of a problem. Then they can email that to a guy on the far side of the base so he can get a better idea of what the problem is.

Attachments / Messaging / Drafts - How do people informally report problem information to each other, and how does this relate to the report drafting process?

In the handheld design there's a difference between exchanging messages to share information about a problem, and actually writing up a report that you're going to file for later. It's one or the other.

Reuse of Old PRs - How do people reference old PRs and why, and how are repeated problems different from first-time problems?

The handheld will bring up problem reports that are similar to ones you're trying to file. You'll use them to copy old problem reports for the repeat problems, and to reference for diagnosing other problems.

Shared Use & Movement - How does problem reporting responsibility and involvement move around the room and the people in it?

The way people use the handheld is, it's carried by the tech lead, and if another guy needs it he calls him over so the tech lead can do the reporting. Then he hands it off to a quality guy when he comes over, and quality submits the report into the system. Then engineers read about the problems that came up from their desktop computer later.

Related Documents - How are related documents linked to a report, who does the linking, and why?

The handheld is designed so that you will link documents like design diagrams and the work order you were following onto the problem report, so the engineer can know what you're talking about.

Concept Validation Results

As our concept validation efforts added clarity and assurance to the basic structures of the models we had already created, and we were unwilling to gamble that remodeling would yield insights worth the time at this late stage, we did not model our validation data. However, the five questions were each answered, to a certain extent.

How do people write on things, why do they do that, and where do those annotations go?
At the Palo Alto Airport, technicians write on diagrams to point out parts needing replacement. They also keep “cheat sheets” of hundreds of part numbers in binders kept in their personal toolboxes, along with the rest of their personal equipment.
Annotated design documents help to add context. Autocomplete is very valuable.

Attachments / Messaging / Drafts - How do people informally report problem information to each other, and how does this relate to the report drafting process?
At the Palo Alto Airport, the service manager and senior technicians serve as filters against superficial discrepancies the younger & lesser technicians found; it’s normal for less than 50% of noted discrepancies to be “legit.” At the Aircraft Maintenance Training School, technicians are said to need “full-time babysitting” for their first 5 years.
All reports are informal and untrustworthy until they are formally vetted by Quality. This earlier stage is congruent with our imagination of a drafting process.

Reuse of Old PRs - How do people reference old PRs and why, and how are repeated problems different from first-time problems?
The Air Force has totally separate paperwork processes for routine maintenance and unusual and dangerous problems; use of each depends on whether or not they are felt by ground personnel to justify a change in the work process documents.
Routine problems require templates for speed; there is a need to signal PR urgency.

Shared Use & Movement - How does problem reporting responsibility and involvement move around the room and the people in it?
At the Palo Alto Airport, technicians at work list short descriptions of discrepancies and their part number locations, and the service manager in a nearby room (as a cross between tech lead and Quality) runs down the list, noting those that are “legitimate.” After this, the service manager enters the discrepancies into the billing software, and the pilot and/or owner of the place judges which repairs are worth it, within FAA regulations.
Technicians list problems. Quality dismisses illegitimate reports and elaborates on legitimate problems. Engineers analyze the reports and decide on corrective action.

Related Documents - How are related documents linked to a report, who does the linking, and why?
Both NASA Arcjet technicians and Palo Alto Airport technicians used photographs to add additional context to reports. At the Palo Alto Airport, pages of design documents (on CD) are printed out and stapled to the paper list of discrepancies the technician passes off to the service manager, with annotations noting the parts that must be replaced.
Techs or Quality can add annotated design documents & photographs, for context.

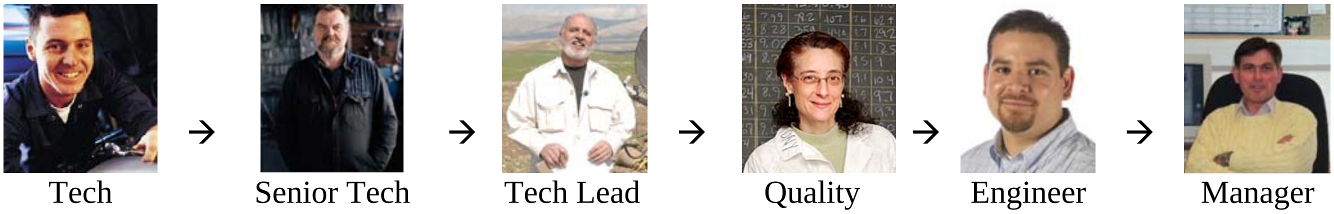
Concept Personas

One aspect in which concept validation helped a great deal was in the way that the additional data made the sequence of problem reporting more compelling by allowing us to further elaborate on the personalities of those involved, through the creation of personas. We were now able to ascribe genuine human characteristics to the people who figured in the process, and the personality traits that suited them to their role.

Furthermore, the extra context demonstrated how there is a definite filtering process that occurs during the problem reporting sequence. Officially, techs report directly to Quality personnel who gave their formal stamp of recognition. In practice, there is a hidden vetting function and several more layers of “virtual Quality” beyond even those formally employed by the various organizations with stakes in the product.

When younger techs find a problem, they turn to older technicians, always including the tech lead, to verify it. It may also pass through the hands of several nearby senior technicians before the tech lead learns about it. At any of these stages, a discrepancy may be determined to be something the new technician simply has never seen before. Only after it passes through this informal “guild” does it move on to become registered with Quality personnel, who add more official layers of oversight.

Quality goes on to officially register the problem. As a result, it is not so much that Quality’s role is to vet, dismiss, and register reports of problems, but that it is Quality’s role to be the last to do so, and the most rigorous. After that point, the problem passes from the informal context of the floor, where everyone meets one another personally, to the formal hierarchy of the engineers and managers, who live and work elsewhere.



This “Quality jump” is the division between the informal technician workspace and what is to them an external authority, and this is congruent with the information we received at the Vertical Gun installation (30) and from the Robotics Professor. (12) Because the technicians’ workspace itself is an informal environment, it doesn’t possess a formal PR system internal to itself; the formal system derives from a structured communication with unseen, unknown members of an external group. This fits with our observations of situations requiring a formal problem reporting system. (B66)

Our goal in this project was therefore to help problem reports make the “Quality jump,” the first contact of a discrepancy with the formal problem reporting system, by redesigning the formal system to enable faster and easier assimilation of new reports, and thereby better integrate the formal PR system with the informality of the technical floor.

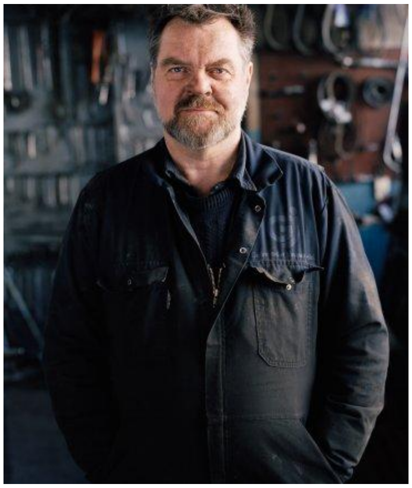
Harold, AKA “Harry” (from VAB and OPF technicians)

Previously a technician with his organization for 3 years, Harry, 28, was transferred to the team at NASA 6 years ago. He prefers to work in teams in case he is unsure about something and needs an extra set of hands to help out. He has gained respect and mentorship amongst the more experienced technicians, learning to work with efficiency and precision; he has excelled at his job very rapidly. Although a quick learner, he still has yet to fully understand the language of engineers and frequently becomes confused, particularly with design documents.

As a younger technician, Harry is enthusiastic about new technologies and is more receptive to them than some of the older technicians. However, he has been disappointed that few new and exciting technologies have been fully deployed in his workspace. Although he wishes that the older technicians were as excited by new technology as he is, he recognizes their experience and respects their opinions.

Harry has been trained to use the problem reporting system, but usually Quality personnel and his team lead handle the actual data entry. Once in awhile he does not know whether he should report a problem that he can fix on the spot, so he always checks with others.

Harry often stays at work overtime. On the weekends, he likes to frequent bars and clubs with his friends.



Fred – Technician (from VAB and OPF technicians)

Fred has been a technician since 1982. He began as a repair tech, and upon completion of a technician certification program, was hired with a NASA contractor. His job can be tough, and he tends to get steadily grumpier over the course of the week.

He takes pride in his seniority, and walks a fine line between using his experience as leverage to push back against management, and doing as he's told. He has the opportunity to advance his position by participating further in higher-level certification programs, but has not yet done so.

Fred has worked with both experienced and inexperienced technicians, as his team varies consistently. Since his work relationships are often transient, he can be gruff and intimidating at first meeting, but becomes more agreeable with time. Although Fred has years of experience working with space-flight technology, he's never liked modern "shiny computer widgets" and prefers using pencil and paper. He refuses to buy a cell phone.

His favorite activities include watching football and working on building projects with his son.

Jim – Tech Lead (from ISS and OPF tech leads)

Jim, 58, is nicknamed the "Chief". He has been working at NASA for 14 years, following 28 years in the Air Force. Formally his title is Tech Lead, but technically he is also an engineer, and trained in many other certifications as well. With an incredible amount of experience, Jim knows all the loops and nothing is unfamiliar or new to him—he is never surprised. He developed some of the software tools used by his team himself. He participates in training technicians and is a living example for how procedures should be completed and policies and regulations should be followed.

Jim is sensitive to the personalities of his technicians, and when a technician's bad day affects the quality of their work, he's learned it's best to send them home. He is also well aware of the disconnect between the younger, less experienced technicians and older, more experienced workers.

Usually he's in his office when not participating in buy-off procedures, but he likes to spend his time on the floor with the crew when he can. Becoming more forgetful as he gets older, he occasionally misplaces his Tech Lead stamp for buy-off procedures, leaving him feeling sheepish.

His personal interests include aviation, fishing, visiting his grandchildren, classic films, and playing poker with his old buddies. To be a good sport, he sometimes loses.

Susan – Quality, OPF (from OPF Quality)

Susan, 42, is a NASA Quality Engineer and has been working at NASA for the 12 years since the completion of her BS in Engineering. Her father, who recently passed away, was a NASA engineer for 35 years; she's always looked up to him.

While on duty, she takes her role very seriously and makes sure that work procedures are performed strictly according to specifications. She does not socialize while working and sometimes feels that others don't conduct themselves suitably for the workplace. She's determined that while she's on the job, everything should be done by the book, perfectly in spec.

She has three children but is able to handle the balance between her home duties and work life well, due to her precise time and task management skills and firm decision making personality – she diligently creates schedules and lists of duties, activities, and responsibilities for each family member every Sunday for the week.

She has enough to fill her time and does not have any interest or time for other activities.

Michael – Engineer (from VAB and ISS engineers)

Upon completing a Master's in Mechanical Engineering from the University of Michigan, Michael began working as an engineer and has been involved with flight launch preparation and flight return at NASA for 4 years. He had been working as a technician for the Air Force for 8 years since graduation from college, where he graduated at the top 10 percent of his class and participated in specialized training during his summer internships.

He is 36, newly married, and planning to move up the hierarchy quickly so that he can support his plans to start a family. He is excited and interested in new technology, and is enthusiastic about the latest Constellation project. Whenever there is an opportunity, he shares his enthusiasm with others.

Michael is very dedicated to his job, feels he is able to greatly impact each mission, and does not take for granted his chance to maintain a major role in keeping the mechanical units safe and ready for launch. Although his work keeps him very busy, he likes to find excuses to get out of his office cubicle and check out the machinery in person.

He does not submit a report a problem report for all the irregularities he finds, frequently passing word along to the local team of technicians. Although he is a younger employee with less experience working at NASA's facilities, he's confident in his skills and as knowledgeable as they come.

He likes meeting new people and has many friends in the area. He enjoys his personal time buying new electronic gadgets, playing basketball, and spending time with his family.

Saul – Project Manager (from LM and Boeing PMs)

Saul, 45, has recently been promoted to a project manager of Operations at NASA within the last two years. Previously he had spent 8 years as a lower-level manager in the Work Control department. He is now in charge of keeping his subordinates on track, gauging their progress, and representing his organization favorably to outside groups through presentations and product demos. Unfortunately, he only infrequently uses the software he demonstrates.

He is responsible for all the people working under him, scheduling, regulating tasks, and keeping track of work progress to make sure work is being both done, and done right. When necessary, he holds his workers to the policies and deadlines of his organization through his energetic, "my way or the highway" management technique. Whenever given a new project, he insists on dramatic improvements, and expects nothing less. He values contacts in other organizations, and tries to maintain a good reputation and good relationships with everyone he meets.

His other interests include golfing, tennis, international travel, and sailing.

Additional Context: Moffett Field Crew Chief

Moffett Federal Air Field is a military airbase located adjacent to NASA Ames. During our push for concept validation, we contacted and interviewed a former Moffett “crew chief,” or helicopter maintenance technician, with prior experience managing projects relating to human-computer interaction for the military.

Problem reporting at Moffett was a recognized problem during his tenure at the base. The flight line, where the helicopters are parked, was located at the northern end of a massive hangar, on the opposite end of the air field from the offices. Crew chiefs logged maintenance records on paper at the flight line, and then made the long walk to the offices to enter the reports into a difficult desktop interface. The flight line was very noisy, and frequently so windy that handling loose paper was difficult.

Recognizing that this might present a problem, the administrators at the base made arrangements for an enclosed booth with a computer station, nearby the flight line. Construction was canceled when the flight line was simply moved to the closer end of the massive hangar.

The air force version of WADs are TOs, or Technical Orders. These were kept in 3-ring binders, were constantly out of date due to regular updates and modifications, and were regularly lost. Due to a shortage of office staff, updated TOs frequently remained in the offices and were never carried out to the flightline. When the helicopters were relocated for service elsewhere, the binders would be loaded on board in special bins, but there were never enough, and so complete sets of TOs were often not shipped.

In case something happens that isn’t covered in a TO, crew chiefs fill out an AFTO-22, a sort of problem report specifically requesting a change in TO. This is unlike NASA, where technicians cannot directly apply for a WAD deviation through the PR system.

AFTO-22s are rated by urgency; “Notes” mean that a reasonably cautious person will remain safe, “Cautions” mean that damage to equipment or injury to personnel could occur, and “Warnings” mean that loss of life or equipment is possible. This rating system is very similar to NASA’s criticality codes.

Normal maintenance records, for routine problems, were kept using 781s. Labeled A through H, these represent the biography of the aircraft, and were kept inside. During maintenance, the 781 was completed, entered at the distant base station, and filed.

The maintenance database was known as CAMS, the Consolidated Aircraft Maintenance System, and logged all Air Force maintenance worldwide. Every technician had a designation called a “man number” which was required for logging on. There was no password, so if a crew chief didn’t have time on his shift to enter the 781 data, he gave his number to the next shift so they could enter it for him. CAMS was, for the crew chiefs, generally useless for retrieval; when reports could be retrieved at all, they were incomplete. As a result, they stuck to using the paper 781 binders at the flight line.

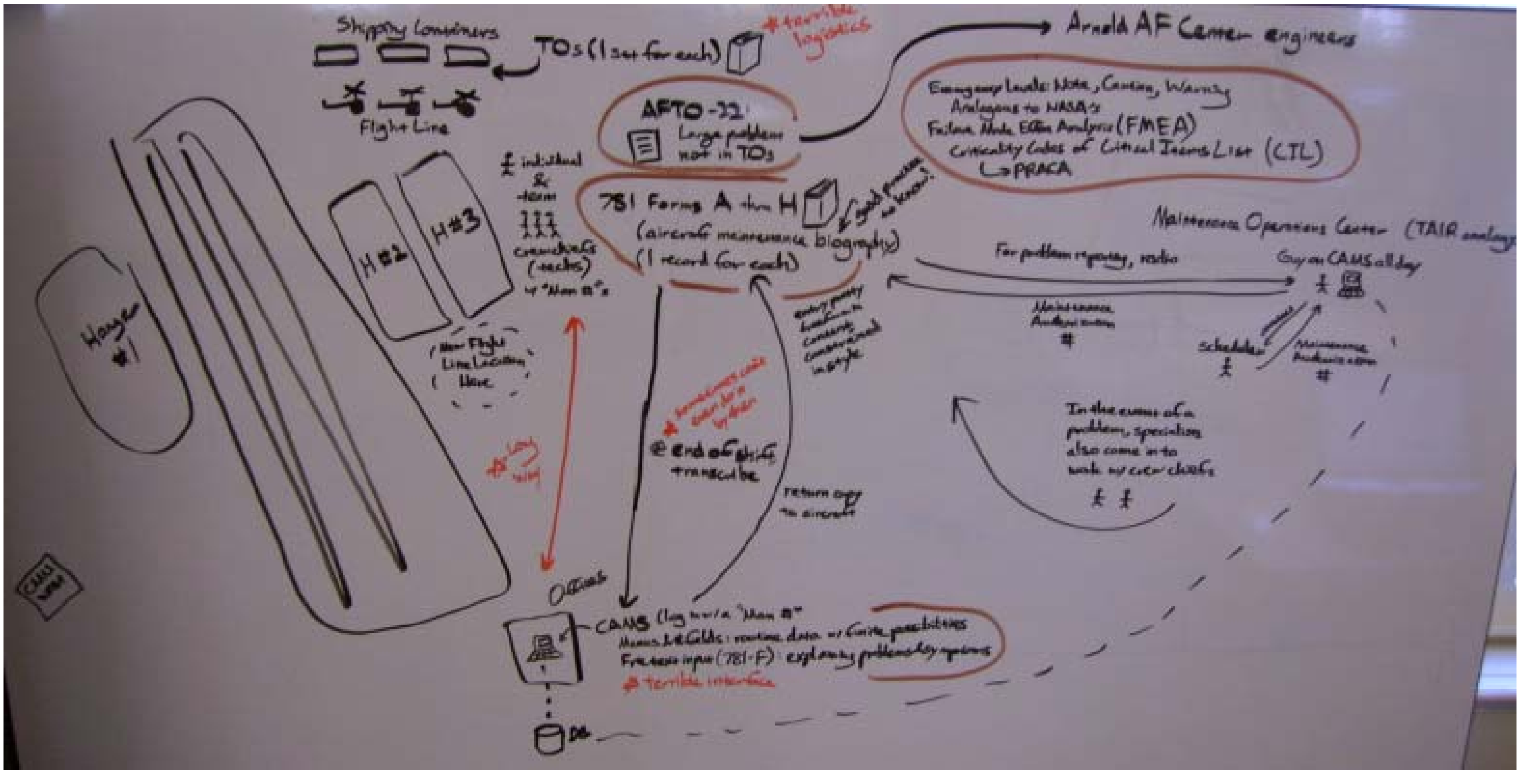
A trademark difficult user interface, CAMS lacked any accurate user guides, and no formal training was given. Invalid data entry crashed it, and once entered, no reports could be edited. This was very frustrating for the technicians, because as the participant said, “I win spelling bees, but I’m a bad typist,” and the need to get the extended data entry exactly correct on the first try was very annoying.

The CAMS interface included both menu selection widgets and free text boxes. For routine entries, the participant preferred the menus. Free text was much better for explaining problems, particularly semidiagnosed, unfixed symptoms.

To report problems, crew chiefs would radio the Maintenance Operations Center (MOC) which had a staff member on CAMS all day. This person contacted a scheduler, and received a Maintenance Authorization Number (MAN), which was then forwarded to the technician, who logged it in the binder of 781s. The problem was then fixed. Afterwards, the MAN was necessary to begin problem report entry into CAMS.

Occasionally, specialists were called in to help crew chiefs with maintenance. These specialists operated under the responsibility of the crew chief, and so while they were experts in their given field, were also watched closely and assisted by the crew chief.

As problems with the problem reporting system became more obvious, an expediter was assigned to carry a two-way radio around the flight line. While not calling in problems and retrieving MANs for the crew chiefs, the expediter did odd jobs. Later on, after the crew chief left the Air Force, CAMS was declared obsolete and replaced.



Traits Signifying Presence or Absence of a PR System

While interviewing the Robotics Professor (12) and staff at the NASA Vertical Gun (30) we encountered situations in which people interacting with an extremely complicated and sometimes dangerous system did not display any need for a formalized PR system. However, in other circumstances, such as while interviewing the HVAC contractor (11) and aircraft technicians at the Palo Alto Airport (29) we found the reverse.

Given that the former, who did not use formalized problem reporting, were generally more highly educated than the latter, who did, and are in fields notorious for complexity, this contrast may appear incongruous. However, we did ultimately uncover data that shows the fundamental need for a formalized PR system, and have created a short list of characteristics that signal the likelihood of its presence or absence.

Organizations with Formalized PR Systems…

…are either of large size, or involve a lone contractor with multiple clients.
…have differentiated roles of builder, designer, and manager.
…have specific roles designated as intermediaries between the other roles.
…place the designer in a position of authority over the builder.
…begin fixing problems immediately after discovering them.
…require communication of problems between strangers who do not meet personally.
…cannot be identified solely by the complexity of the systems they manage.

In short, anonymous external authority requires formal and non-personalized communications. Writers do not personally know the person reading the report, and it is unlikely that they will meet them in person; as a result, reports are dictated to be rigorously completed to ensure no misunderstanding on the part of the authority.

The same rules apply equally to NASA's contractors and those to be found in other independent technical occupations. In the latter cases, the engineers work at an independent parts manufacturer while clients play the part of managers. However, the fact that they are strangers still results in the need for a formal system of invoices.

In contrast, at the Vertical Gun and in the robotics laboratory there were only very few staff and clients, all of whom could meet personally. As a result, there was no gap between the groups; they all shared common and informal knowledge, and no automated record of that knowledge was needed. It is only where there are boundaries preventing constant and personal contact that a need for an automated social understanding exists.

After identifying these characteristics, it also became clear that the powering force of the PR system is actually the informal reality of the technician. Technicians communicate internally and informally about a problem before allowing it to move through a final intermediary (Quality) and onwards to the far side of the divide. The more we design the formal PR system to better integrate with this informal system of communication, which itself cannot be redesigned, the more successful our formal system will be.

Johnson Space Center Contextual Report

In mid-July, two members of our team were able to accompany a client on a trip to Johnson Space Center in Houston, Texas. The original goal of this trip was to test the current working model of the interface on the Symbol device. Since our plan was to talk to several high-ranking Constellation team members and a number of technical managers, we thought it possible to get some real-life use out of our prototype. However, as it turned out, scheduling issues prevented us from being able to meet with representative users. Instead, we were able to gain an enormous amount of insight that radically changed our design from the interviews we had. Among the people we were able to talk with were: two managers, three engineers from a NASA contractor with industry experience, and two quality engineers from GFE. They have been given pseudonyms for their protection. All of these people had immense first-hand experience with some of the problems in PRACA, and many had previously worked in situations with better PR systems, giving them a very valuable perspective for us to learn from. Through these interviews, we were able to gain the following important design insights, which will be explained in the proceeding pages:

- The device should be designed such that the initial problem report can be filled out quickly from the device.
- Technicians that are filling out the reports should not be required to know any context for the problem they are reporting. They need only report what they can see in front of them.
- The device should be able to scan serial and part numbers with barcodes.
- The device should keep a history of PRs tied to a particular part, along with other part information. This could include next-higher assemblies, manufacturer information, calibration information, certification information, troubleshooting documents, and where the part is deployed.
- Allow for the possibility that the handheld will be used by manufacturers.
- The technician filling out a report need not know to whom he or she is supposed to send it. They simply enter it into the system and can safely assume that it is being handled by the appropriate supervisor or quality assurance personnel.
- Our current form for problem reporting was much too long and cumbersome.
- Our current form was misleading, as no one person would ever fill out both report information and analysis information.
- All reports must be entered into PRACA, no matter how trivial.
- Quality personnel should be able to perform check-off audits on handhelds.
- There is the possibility that many facilities will have limited or no wireless connectivity.
- The device can store information on a particular technician, such as whether or not they are certified to use a particular piece of equipment.
- Problems should be searchable such that if they are accessed by an engineer 20 years from now, they should be readily understood and analyzed.
- No analysis should ever take place on the floor. Only basic reporting.

- As it stands, looking up a past PR for analysis is a laborious task. In the future, mission personnel should be actively notified of relevant PRs by the system in real time. They should not have to look PRs up.
- After a report is filed, the device should ask a series of troubleshooting questions related to the specific problem for additional, useful information.
- The interface needs to be separated into different ones for the technician, quality, and engineering roles.
- Engineers like to be able to send messages with PRs back and forth as part of problem resolution, especially with attached photographs.
- Quality personnel would like to be able to use software to replace physical stamps on paper.

July 10, 12pm. Meeting with "Francis"

Francis has been with NASA for a number of years. He is an engineer for GFE, a contractor working with NASA that makes everything from hardware to space suits to astronaut undergarments to space food. We met with him at noon on our first day because he was very disappointed with the current way that PRACA works and had a vision for the way he believed it should work. When he heard that Constellation was working on a PRACA system that could be deployed NASA-wide, he was very excited and wanted to share his vision with us in hopes of guiding the new program away from the pitfalls of previous PRACA endeavors. Francis was also interested in the idea of handheld devices being an integrated part of this system.

Having also worked his way up the ladder from technician to engineering manager in industry, he began by talking about the primary failure of NASA PRACA. "In industry, in a given hour, you spend five minutes putting information in the system, and the other 55 minutes would be spent analyzing, mining, testing, etc," he said, and went on to say that it was simply more important in industry to see if a problem could be duplicated and characterized. At NASA, he said, that same hour would be spent "worrying about the system and who has access to it, but I see no evidence that anyone is using it." Francis said that he was aware of analysis and investigation, but that it did not appear that it interfaced with PRACA.

After describing his problems with the current system, Francis began to talk about his vision for how PRACA *should* work. He began at the bottom level: the technician who discovers a problem. According to Francis, "the person who discovers the problem is almost always the one who knows the least about it." In saying this, he was by no means slighting the training or knowledge of the technician, but realistically portraying the fact that technicians may or may not know anything about a given piece of equipment. They know what they can see, that the equipment is broken, what it looks like, and any serial or part numbers displayed. Often, he said, a technician would have little to no knowledge about who had manufactured the part, what mission it was a part of, or how it should be fixed. Their job is simply to report something when they find that it does not appear normal.

Francis also stressed the importance of keeping track of a given part’s history all the way up and down the supply chain, something that the current PRACA fails to do. As an example, he used the story of a part that had a problem in the manufacturing plant that was diagnosed and fixed. However, every time the part reached a new individual, they noticed the problem and reported it, wasting valuable time that could have been saved if they had access to a report showing that it had already been fixed and was flight-ready, even despite the visible flaw.

As a means of resolving this disconnect between manufacturing, shipping, assembly, maintenance, and eventually problem analysis and resolution, Francis brought up the idea of structuring the system intelligently so that no individual link on the supply chain is under-informed. As it stands there tend to be difficulties wherein a problem is noticed, but the technician does not know to whom it should be reported. In Francis’s ideal world, the technician would report it to the system, and it would be up to PRACA to determine where it goes and to make sure that it gets there. That way, there is no hesitation in reporting something, even if the technician does not know what it is or to what it pertains.

While no formal user test was conducted, Francis strongly disagreed with how we had structured our device. “You’re asking the wrong questions,” he said of our four-tab, vertically-scrolling interface. As we began to understand his ideation of the perfect PRACA, we asked him what he thought about the idea of simply a text box for description and button for submitting. To that he responded, “now you’re on the right track.” He said that the “core” information is all that is important. Taxonomy, to him, was a non-issue. He said that even a description such as “while working on step 3 of tps [some number] I found a broken…” was poorly written. This is because 20 years down the line, anyone wishing to look at that report would have to look up the TPS and the workstep to gain any context into what had happened. At this point, we wrapped up our discussion but made plans to visit again to finish up our talk.

July 11, 8:30am, meeting with “Archie”

Archie is a contractor with whom we met to discuss the GFE problem reporting process. He started out the meeting by describing how an anomaly at GFE gets reported. This process is highly indicative of what is wrong with the current PRACA system. A problem is first reported as a discrepancy report (DR). After a DR, if it is deemed serious enough, the reporter must fill out some combination of nine different PRACA forms, depending on the nature of the problem. All of the DRs make it into a database called QARC, which stands for Quality Assurance Record Center. Unfortunately, the output from this database is minimal, so it requires a request of the actual document to be really helpful. Worse still, GFE’s PRACA reports are spread out amongst four different databases and two completely different reporting systems.

We were able to examine some of these reports. They were very cluttered and difficult to understand. However, we were able to echo support for our idea of photo annotation, as several of the DRs and PRACAs had pictures that were drawn on with a pen. Along the lines of annotation, we inquired about whether or not a DR would ever be edited. Archie responded that if anything, they would just "redline" it, referring to physically changing it with a red marker. When asked how useful the resulting data was, he called it a "sad story."

The content of the photographs was sometimes hard to discern, an unfortunate breakdown that an attempt to clarify data may have only made it harder. The particular DR in front of use was being used by the contractor Wyle, who had passed the same problem off to NASA without ever filing a PRACA. The problem had been dispositioned twice, but it still was recurring. This was a great example of why every problem should be entered into PRACA.

July 11, 3pm, meeting with "Charles" and "Murray"

Charles and Murray are two managers for Constellation. Our conversation began with Charles talking about where he saw handhelds fitting into PRACA, especially from a quality standpoint. He said "I want all of NASA to be using PDAs to do spot-check audits. A program should randomly select something to be audited, so you can't be prepared except by doing your job." Then he said that he wants QA engineers to be on the floor doing check-offs directly on handhelds.

Charles described handhelds as more efficient for a number of reasons. First of all, they saved time that is taken to process paper reports. Additionally, they are easier to search, save paper costs, and are in Charles's view more professional. He described mobile auditing as "the way we oughta be doing business." Part of this process, Charles said, is minimizing inconsistency. This would come from bringing the fragmented pieces of PRACA together, and also by keeping the problem codes standardized, with the help of computers. Regardless, he said, training is an essential aspect of this transition.

Charles talked about how handhelds in the manufacturing world can be used to cut costs dramatically by catching flaws early in the process, so that anomalies are caught before large numbers of pieces of costly equipment are produced. Regardless of whether in a manufacturing or maintenance, context, however, Charles said "we want to put everything in the system. If it's no big deal our process allows us to close it out quick." This is a far leap from the system in which a discrepancy report could be closed out before ever being entered into the PRACA system.

One downside of adding handheld technology, however, is that there is unchecked speculation that wireless internet can set off "pyros." Pyros are parts of the space ship that are expected to be sensitive to wireless. By Charles's explanation, they do not know if this is true or not, but they are so rare and expensive that testing it is not worth the risk. This may mean that wireless capability in PRACA handhelds will no be usable at all centers. Additionally, Charles said that it might be difficult to get contractors to use PRACA handhelds. He said that because of the way NASA pays contractors, there is no financial incentive to be particularly time-efficient. This means, he said, that NASA might have to pay for handhelds for contractors.

An interesting use case for a technician handheld was brought up in this meeting. While it is not particularly relevant to PRACA, it is a strong argument for why handhelds in general may be a good idea. Charles described a case where a technician's job is to torque a piece of equipment using a torque wrench. However, not everyone is certified to use a torque wrench, and each wrench must be calibrated every so often in order for work done with it to be considered valid. A technician could use a hand held to scan the bar code on the wrench, and then his ID card. It could tell him whether or not the wrench needed to be calibrated, and also whether or not he had the required certification. This could save an enormous amount of time and money in work steps that do not have to be redone because of such oversights. Finally, the device could save time and reduce error by reading the output of the torque test.

Charles and Murray were very receptive to the idea of rich media on the device. They liked the idea that a technician could record voice for his own personal memory, take pictures and videos, and annotate them for an increase in clarity if there is a vague problem. Charles added, "I want to look at a PR 20 years from now and know exactly what it's saying." He went on to say something that would be echoed by Francis that technicians *report*, whereas engineers *solve*, and there is very little overlap.

Additional uses for handhelds discussed in the meeting include inventory information and remote emergency information during a launch. For example, if a technician needed a particular tool, it is possible that his/her handheld could tell if any other technician was using it, or where it was being stored. The remote launch refers to a time when a craft is being launched from a place such as White Sands, where the technicians are in a remote area and would need access to emergency documentation that otherwise could not be readily available.

July 12, 8:30am, "Francis," Second Interview

We met Francis again on Thursday morning, and again he opened with a problem he saw in PRACA. "In a given month, there would 4100 discrepancies that were dispositioned. In order to see what was done, you'd have to go to the meeting minutes individually and open up the power points," he said, pointing out the inefficiency of data retrieval. This difficulty leads, in his opinion to a lack of the important analysis that is so stressed in industry. He went on to say that of those 4100 dispositions, a shockingly small amount actually ever made it into PRACA. Having a single database with a single interface would increase the effectiveness of both entry and retrieval of problem reports and become a huge cost saver.

Francis advised us not to discriminate what goes in to PRACA, and certainly not let the technician make that choice. In order to illustrate his point, he talked about how he recently posted an item for sale on eBay. He had no advance knowledge of who his buyer would be, he just posted the information he had, and the system took care of the rest. He went on to tell a story about a technician who was pouring a chemical called MEK in a facility. While he was pouring a particular barrel, he noticed that it was discolored, so he reported it. The discrepancy was handled by a quality assurance technician, on paper, and never made it into PRACA. As a result, the engineers for the mission that the equipment was associated with never knew about the problem until they had to delay the launch at the last minute.

The engineers were furious that they were informed so late and wondered why they did not receive notice of the problem, while at the same time the technician who reported it was hailed as a hero at his space center. Of course, both parties were correct. The technician had gone above and beyond his job description, and the engineers should have known about this potentially disastrous problem. This is not even to mention the fact that that barrel may not have been the only contaminated one, and that perhaps the problem was not with that particular barrel but was a problem at the MEK manufacturing plant. In Francis' opinion, PRACA as a system was to blame for this miscommunication. It is so modular and mission-specific that it is no wonder that the people who were responsible for reporting the problem had no idea that they needed to tell someone else about it.

Taking it a step further, Francis said that he believed that analysis being done on the floor "is one of the greatest threats to flight." Maintenance people should find and report problems, and engineers and managers should analyze and diagnose them. Francis believes that technicians, properly trained, will do a good job of entering reports, and that handhelds are important cost- and time-savers. He debunked any idea that contractors would not have to use them, a concern of the group's up until this point.

As we wrapped up our discussion, we talked about a couple of specific features that he would like to see. First, he thought that troubleshooting questions should be brought up automatically when a bar code is scanned. This simply provides more information for whoever is next on the process without forcing the tech to know any information he/she should not be expected to. The barcode should also bring up a history of the part, Francis said. We finished by summarizing the work flow as Francis saw it unfolding: A technician finds a problem and immediately writes out a basic report of what he can see on a handheld or nearby terminal; if possible, the intelligent system pops up an automated test or diagnostic questionnaire to gather additional, problem-specific information; a quality assurance employee receives the collected data and performs his own series of check-offs and diagnostics, again requiring no high-level knowledge of the system or mission; finally, the engineer receives the full report and begins analysis and corrective action.

Thursday, July 12, 2pm Meeting with "Tom"

Tom is an engineering manager with NASA. Our meeting started off with our client asking him some questions regarding work authorization and how it could interface with PRACA. Tom responded that he did not want PRACA to include work authorization because it could result in the WAD system being fragmented into two distinct parts.

After some discussion outside of the scope of this project, Tom brought up a problem in the parts database. He told an anecdote about a flaw in a particular hook that is used on a number of different parts. The problem was that even thought they knew about the problem with the hook, they could not look up and retrieve data that said what next-higher assemblies were using the faulty hooks. While it is not our intention to actually implement anything involving the parts database, it seems important that our device properly interface with them. Scanning a part should be able to bring up information about the manufacturer, which next-higher assemblies it is being used in, and other useful information that is presently unavailable.

Tom went into detail on a concept that Francis had touched on: the idea of a PRACA "dashboard." This would mean an Outlook-esque application that operates separately from but similarly to an email client. He warned against his own suggestion, though, that it is easy to "flood the system" with overwhelming notifications in this case, and that having this application and email might be confusing. He went on to say that email is also not immediate enough for a real emergency: "email is not the right way to work mission critical problems, though I see it happening."

Another suggestion of this was the prioritizing of PRs. He said that close to launch time there is often a flurry of problems that need to be dealt with in a rapidly-closing time window. A reliable way to prioritize problems would help with that crunch at the end of the preparation period. He liked the Quick Mode design, and suggested that scanning a bar code recognized to be, for example, a part number, would automatically fill it in without even necessitating opening the New PR application.

When our conversation turned to photographs of problems, Tom made it clear that these are not only very useful as a potential future feature, but are also regularly used in the current process. Examples he came up with included what he called "close-out photos," rapid faxes with KSC, and general problem reporting. Close-out photos refer to pictures taken at the end of a resolution, so that the next person who encounters the problem can decide for themselves if the anomaly is different enough from the close-out to warrant being labeled as such. In dealing with engineers at KSC, sometimes engineers from JSC need to be included on problem analyses, but are unable to travel down to the Cape to do so in person. Tom described a current process in which pictures are faxed or emailed back in forth in near-real time for teams to collaborate across great distances. He added that these features being included on a mobile device would be very useful.

Finally, we discussed why paper was still the standard, especially at a place like NASA. Tom offered that "paper is quick, it's easy to modify, and you can show it to other people. However…you can lose it, and that's not good." He also added that stamping on paper is something that they have not seen a satisfactory digital solution for. "The biggest obstacle is the hardware/software combo that replaces the physical stamp on paper."