Application Oriented R&D: Aphorisms & Anecdotes

Some of what I think I learned about leading and managing it in 55+ years of practice.

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Application Oriented R&D

Motivated by questions or problems from others.

or (sometimes):

From oneself, pretending to be one of the others.

(eg: If I were so and so, what would I want?)

Nature, to be commanded,
must be obeyed.

- Francis Bacon, 1561 - 1626

My Experience:

- Scientist & Dir. of Hudson Labs. (Columbia), doing research for ONR
- Dir. for Nuclear Test detection, Dep. Dir. ARPA
- Assistant Secretary of the Navy for R&D
- Assistant Executive Director UNEP
- Assoc. Dir. for Applied Oceanography WHOI
- Administrator of NASA
- VP of GM in charge of Research Labs.

Some Aphorisms and Anecdotes

All application oriented R&D organizations are alike.

Scale is important, but organizations generally are hierarchical, and therefore self-similar, fractal:

Boss supervising several workers:

Each worker, as a boss, supervising several workers:

Etc., etc.

A hierarchical stack of similar small organizations.

Of course:

The official organization may not be (usually isn’t) the REAL organization, which is likely to be a partly overlapping set of networks of various sizes, usually with hierarchical embedding.

(Anecdote: Parts chasing)

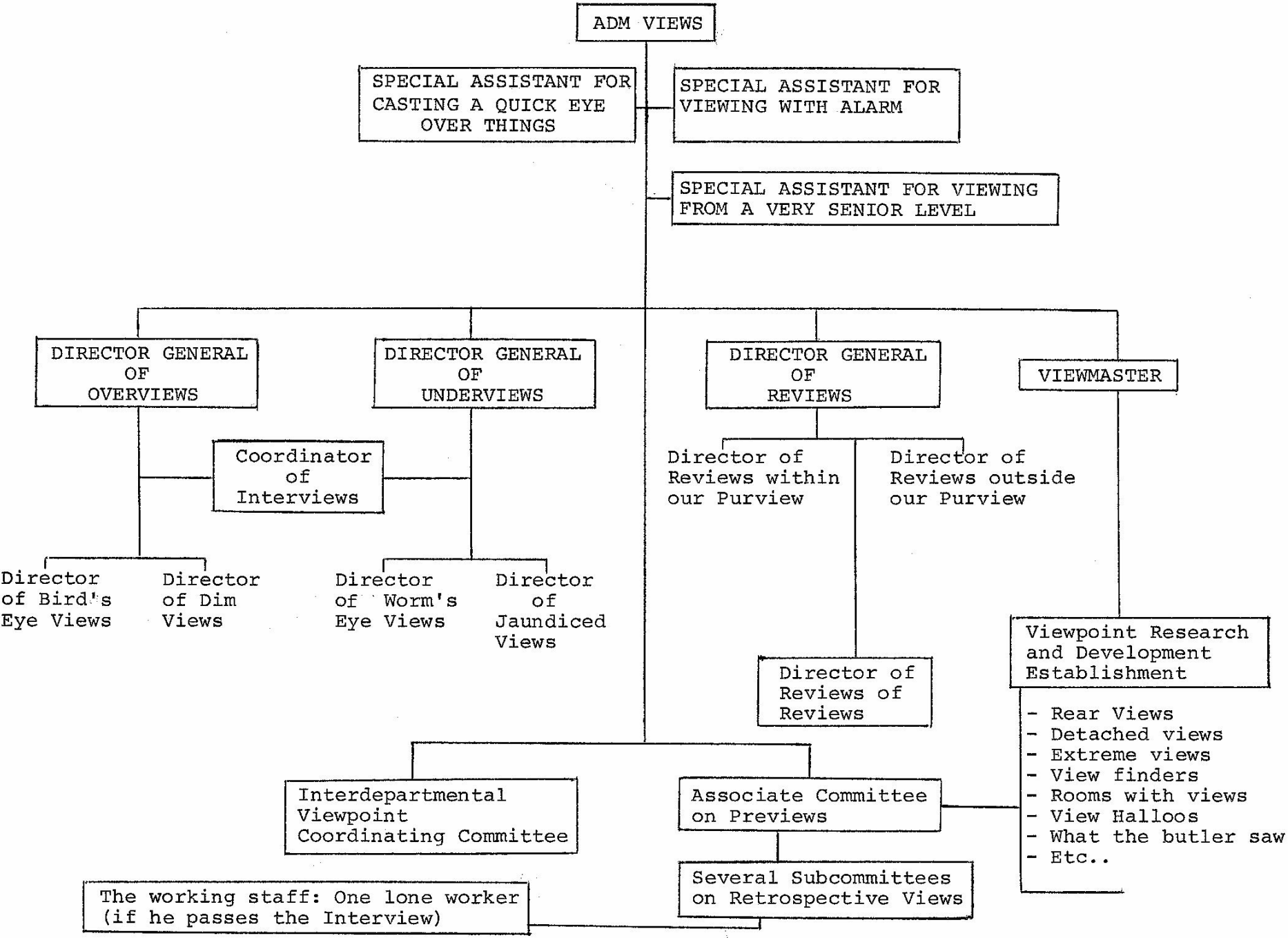
Bureaucracy, Rules, Policies, and Standards are all necessary but:

No one who is obeying ALL the rules can possibly be doing any work!

(Why the “work to rule” non-strike is so devastating!)

(Why R&D organizations tend to be rather relaxed and chaotic!)

NON SEQUITUR *by Wiley*


ADM VIEWS
SPECIAL ASSISTANT FOR CASTING A QUICK EYE OVER THINGS
SPECIAL ASSISTANT FOR VIEWING WITH ALARM
SPECIAL ASSISTANT FOR VIEWING FROM A VERY SENIOR LEVEL
DIRECTOR GENERAL OF OVERVIEWS
DIRECTOR GENERAL OF UNDERVIEWS
DIRECTOR GENERAL OF REVIEWS
VIEWMASTER
Coordinator of Interviews
Director of Reviews within our Purview
Director of Reviews outside our Purview
Director of Bird's Eye Views
Director of Dim Views
Director of Worm's Eye Views
Director of Jaundiced Views
Director of Reviews of Reviews
Viewpoint Research and Development Establishment
- Rear Views
- Detached views
- Extreme views
- View finders
- Rooms with views
- View Halloos
- What the butler saw
- Etc..
Interdepartmental Viewpoint Coordinating Committee
Associate Committee on Previews
Several Subcommittees on Retrospective Views
The working staff: One lone worker (if he passes the Interview)

Early in R&D, discipline is generally embedded in the trained scientist’s, or engineer’s, work habits; this is usually informal.

As R&D continues towards production, formal discipline must increasingly be purposefully embedded in the work process.

The customer for R&D is always wrong.

-Misstated problems:

Customers say what they think the answer is,
not:
What the question on their minds really is.

ie: “What I want is…,”
not:
“My problem is…”

- Besides:

How would they know the technical possibilities?
How would technologist really know what they want?

“We need a faster fighter aircraft!”

After dialogue, really ended up meaning:

We need a better, longer range, air to air weapon.”

Buying R&D is not like buying shoes!

- Shoes exist, and can be seen, and tried on.
- R&D is about future possibilies that don’t exist, can’t be seen, and can’t be tried on.
- ‘Requirements’ are guesses about possible futures.
- Specifications don’t really specify:
    - They can only be an incomplete sample (tacit knowledge)

A Requirement

Navy helicopter requirement:

Take off from 14,000 feet on a
90°F day!!!???

(There is no such place!)

Tacit Knowledge

The day the Hughes TWTs suddenly started dying too soon:

Must weld the filaments in with the tube upside down!

Inventing and defining problems is generally even harder than solving them!

The one who says it cannot be done should not get in the way of the one who is doing it!

- Said to be a Gaucho proverb

Application oriented R&D is a contact sport, fueled by dialogue, discussion,and argument.

An **<u>early</u>** dialogue between customer for and supplier of R&D is necessary for success.

Arms length dealing doesn’t work!

but:

Continuing attention and discipline IS required!

A **continuing** dialogue between customer and supplier is needed.

Discipline is required in this dialogue,
but:
Arms length dealing does not work!

(Everyone involved has a conflict of interest or a bias. That's ok as long as everyone knows this.)

("Trust but verify."
- Ronald Reagan)

“The best fertilizer is the footprint of the owner.”

- Said to be a Sicilian proverb, probably dating back to an anecdote of Pliny the Elder (died 79AD at Pompeii)

It is easy to know what is relevant; impossible to know what is irrelevant.

Polymer door rib ‘read through’

Comment by customer:

‘It must have been an easy problem, you guys solved it in two weeks!’

Response from R&D:

‘Easy after twenty years of thinking about such problems!’

Scheduling assembly plants

Luncheon conversation re intractable computational problem:

Engineer:

‘We’re stuck…’

Mathematician:

‘It sounds familiar; I think there may be a theorem.’

ACuZinc

AlCuZn alloys for “one day die”

(and, by the way, the customer specified the wrong problem, but we couldn’t convince him; he was my boss, and already knew how to build cars!)

Never put into practice (at least then), but the alloy knowledge later made it possible to solve an important problem very rapidly,

and made new products possible.

Application tasks require knowledge matrices

Knowledge Matrices

- A more efficient, lower emissions auto engine involves:
  - combustion chemistry
  - electric spark/plasma physics
  - fluid flow
  - heat transfer
  - mechanical systems
  - materials
  - etc., etc., etc…..
- And then the next level down of detail…..
  - Etc.,etc.,etc…….

Knowledge Matrix: An Example

	Chem	Mech eng	Elec eng	Comp eng	Ther-mo	Mat'l phys	Fluid flow	……	…….
comb	X								
fuel	X								
lube/ frict.	X	X				X	X		
cool'g					X		X		
mat'ls	X				X	X	X		
cntr'l		X	X	X	X				
heat trsfer		X			X	X	X		
mech dyn		X		X		X			
……									

Therefore:

Application oriented R&D needs central organization of some kind

(At least matrix management, formal or informal.)

Besides:

The organization may need (eg) mathematicians all the time, but any division may need one only infrequently,

and:

The division may not even know when it needs one!

Good application oriented R&D organizations do much more than R&D:

Some Tasks of Industrial R&D Labs

Product Development

Process Development

Problem Solving

Eye on the S&T World

S & T Memory and Perspective

Education and Training

Two management systems:

MBWA: Management by Walking Around

- David Packard

MBAQ: Management by Asking Questions

- Bob Frosch

Some Sample Questions

- What can/may/will go wrong?

- Why are you doing this?
- Who wants it? Why?
- How will it be serviced?
- What is it likely to cost?
- ……..

A question:

About a ship being (re)designed to hold a very heavy object on a long string:

“What happens if the string breaks?”

“It can’t break.”

“But, suppose it does…”

……..

Some Additional Anecdotes

- SOSUS array length and depth
- Shuttle tiles and ‘felting’
- Shuttle tail, & control redundancy
- Assembly scheduling
- Theory of manufacturing
- Thin shell die casting
- “read through”
- Iron casting cupolas
- SWATH ship/facility Kaimalina
- The day most of the Sonobuoys stopped working
- Hybrid cars
- Intelligent cars

Technology “Transfer”

By people with knowledge and skill

Not by paper!

Anecdote:

Synthetic alumni

Think of pieces in the larger system context:

universe

|

earth

|

society, laws, regulations

|

road system

|

vehicle on road with driver (in traffic)

|

vehicle (with fuel, oil, etc.)

|

power train

|

engine

|

ore------->iron------>cast------>machine------> engine block ---->re-melt---->recast---->new block (+scrap)

|

iron, carbon, …

|

Fe, C... atoms

|

nuclei

|

protons, neutrons, quarks...

|

vacuum

Measurement of application oriented R&D organizations:

Only over time

Only whole organizational pieces:

NOT by project by project success

What should the success rate of projects be?

100%, 90%, 50%, 10%, 0%?

NASA Center Director:

Everything my lab did last year was successful!

Response:

Are you going to try something difficult and risky this year?

The success rate should be such that the organization, or piece of the organization, ‘pays it’s way’ in $, or other contributions to success.

[In a sampled year at GM Research Labs ~12 projects out of ~120 (~10%) put into company use gave the total Lab an IRR of 70+%!]

Further note:

For a complicated product (eg: vehicles) its easier to track process and production improvements than product improvements.

(eg: The value of an improvement in combustion efficiency gets lost in the rest of the changes to the design.)

Production cost, time, or labor and machinery changes are relatively easy to track.)

A successful R&D organization
is not sufficient to ensure
successful operations,
or a successful company!

GM Research Organization 1990:

Vice President

- Physical Sciences
- Materials Sciences
- Engineering Sciences
- Research & Administrative Services

- Assigned to VP from other Staff:
  - Personnel Unit

Physical Sciences

- Computer Sciences
- Computing systems
- Electrical & electronics Engineering
- Mathematics
- Operating Sciences
- Physics

Materials Sciences

- Analytical Chemistry
- Biomedical Science
- Environmental Science
- Fuels & Lubricants
- Metallurgy
- Physical Chemistry
- Polymers
- Division & Staff Contacts

Engineering Sciences

- Engine Research
- Engineering Mechanics
- Power systems Research
- Thermosciences
- Vehicle Systems Research
- Engineering Research Council
- Vehicle/Highway systems Coordination

Research & Administrative Services

- Instrumentation
- Processing
- Technical Information

Assigned to GMR from other staffs:

- Facilities operations
- Processing
- Labor Relations
- Safety

Physics

- Atomically Engineered Materials
  - Semiconductors
  - Metals
- Computational Physics
- Magnetic Materials
- Light Control Materials
- Advanced Materials & Processing
  - Optical & Ignition Physics
  - Materials Physics

Mathematics

- Statistics
- Computational Mechanics
- Mathematical Analysis & Computation
  - Analysis
  - Computation
- Applied Mathematics
  - Control Theory
  - Operations Research