Assembly Workstation Design Issues

- Goals of this class
  - understand workstation elements
  - look at part feeding and presentation alternatives
  - design a process and a single station system for it

Assembly = Reduction in DoF Uncertainty

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Source:
Figure 17-1 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

What Happens in a Workstation

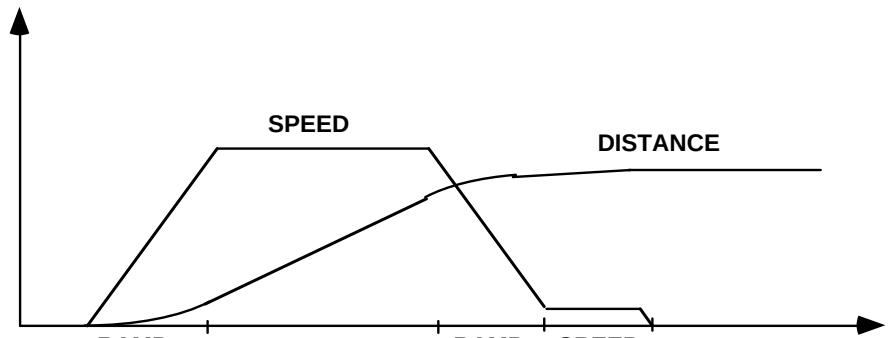
- An incomplete assembly arrives (or several at once)
- Parts to be assembled arrive
  - as single parts
  - as a subassembly
- Parts may have to be separated, oriented, given a final check
- Parts are joined to the assembly
- Assembly correctness is checked
- Documentation may have to be filled out
- The assembly is passed on to the next station

Major Issues

- Get done within the allowed cycle, which is usually short
- Avoid the three common errors
  - wrong part
  - correct part installed wrong, damaged, or causing damage to the rest of the assembly
  - bad part used anyway
- Error-proofing or poka-yoke
- Handle a lot of distractions

Cycle Time

- Varies from milliseconds for cigarettes to days for aircraft
- Components
  - work in/out
  - move to get tool
  - move to get part
  - move to insertion point
  - insert
  - move to get new tool
- Each move includes accel-steady speed-decel-creep



	RAMP UP TO FULL SPEED	RUN AT FULL SPEED	RAMP DOWN	CREEP
% TIME	22	40	38	
% DISTANCE COVERED	14	68	18	

60% OF THE TIME IS SPENT COVERING ONLY 32% OF THE DISTANCE

Simulation Software

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Source:
Figure 17-15 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

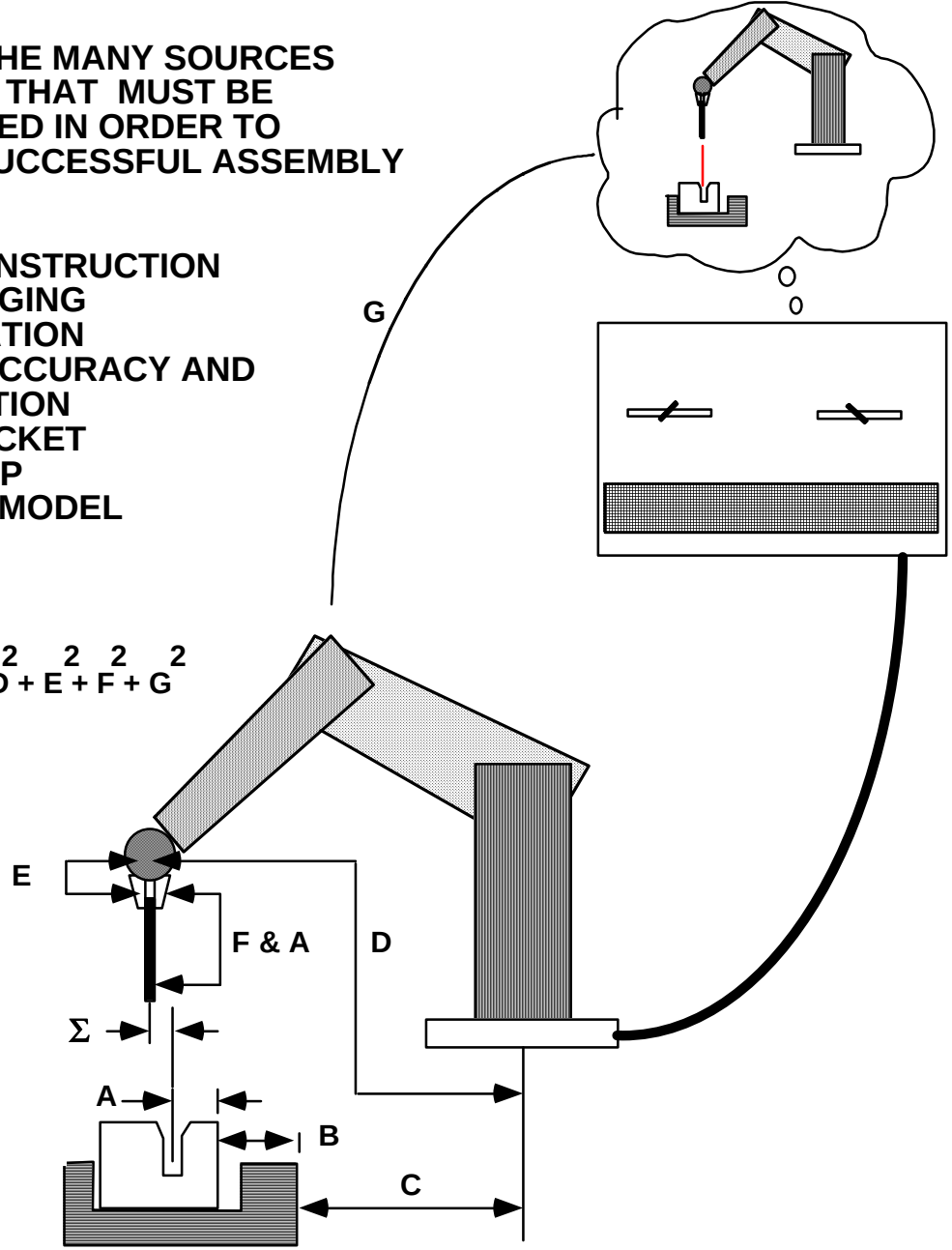
Coordinate Transfer and Part Control

- Machine assembly requires transfer of coordinates
  - from where part is palletized to where it is gripped
  - from where it is gripped to where it mates
  - grip points may or may not be functional features
- These coordinates are usually on different locations on a part
- From each of these coordinates runs a chain of coordinate frames back around until they meet at the point of assembly

SOME OF THE MANY SOURCES OF ERROR THAT MUST BE CONTROLLED IN ORDER TO ACHIEVE SUCCESSFUL ASSEMBLY

A. PART CONSTRUCTION
B. PART JIGGING
C. JIG LOCATION
D. ROBOT ACCURACY AND CALIBRATION
E. TOOL SOCKET
F. PART GRIP
G. OFFLINE MODEL

$$\Sigma^2 = A^2 + B^2 + C^2 + D^2 + E^2 + F^2 + G^2$$



Assemblability

Some Important Decisions

- Choice of assembly “resource”
  - cost, reach, speed, multi-task capability, load cap, dexterity, etc: people, robots, dedicated/fixed
- Part presentation at the station or elsewhere
  - accuracy of palletizing or carrier strips almost the same as that of assembly
  - economics of palletizing: how/who; pipeline of WIP
- Serial vs parallel parts presentation
  - vibratory bowl or parts strip vs pallet
- Tool change vs multi-purpose tools
  - similar issues apply to manual and robotic

Small Parts Feeder

Image removed for copyright reasons.
Source:
Figure 17-4 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Large Parts Feeder

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Source:
Figure 17-5 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Other Important Decisions

- Allocation of degrees of freedom
  - all in one place
  - shared between two, as in 4 DOF robot and 2 DOF workholder
- Combinations of fab and part arrangement with assembly
  - creates parts or subassemblies on the spot
  - examples: pre-assembly of valve keepers, spring winding, lubrication, sorting

Valve Keepers

Image removed for copyright reasons.
Source:
Figure 5-4 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Workstation Layout

- Part presentation
  - Automatic feeders
  - Chutes loaded from opposite side
  - Bulk parts vs kits
- Station layout to provide
  - Parts and tools within easy reach
  - Things laid out in process sequence
  - Instructions - paper, video for each version
  - Instructions - what version is this
  - Documentation - tests performed, parts installed
- Line layout to provide
  - Space for materials at lineside
  - Space for transporters

Sony APOS

- Offline shakers fill pallets (~ 10” x 12”)
- Part jams, if any, occur off line and do not stop the assembly system
- Rather complex parts can be presented automatically
- Pallets occupy considerable space at the workstation
- The robot spends a lot of time slewing over to the pallet to get a part
- So you trade time for space: do you win?

Sony APOS - Palletizer

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Source:
Figure 17-6 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Sony APOS - Assembly Station

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Source:
Figure 17-7 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Other Architectures

- Escort parts and tools (early Sony FX-1)
- Flexibility based on station lockout
  - one simple station per part or version thereof
  - assembly passes through unneeded stations
  - lots of floor space
- Roving robot (Hitachi, 1980)
  - carries assembly in its “lap”
  - visits stations that feed parts and hold special tools
- Roving robot teams (Denso, 2000)
  - Robots carry tools, assemblies ride conveyor, parts delivered at stations
  - Robots can be added or removed from system to adjust capacity
  - Robots can share work at highly loaded stations
- Parts made in or fastened to carrier strips - separates part prep from part feeding for higher feeding reliability

Sony Walkman II

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Source:
Figure 14-15 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Sony Phenix 10 System

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Source:
Figure 17-20 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Parts Tray

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Source:
Figure 17-21(a) in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

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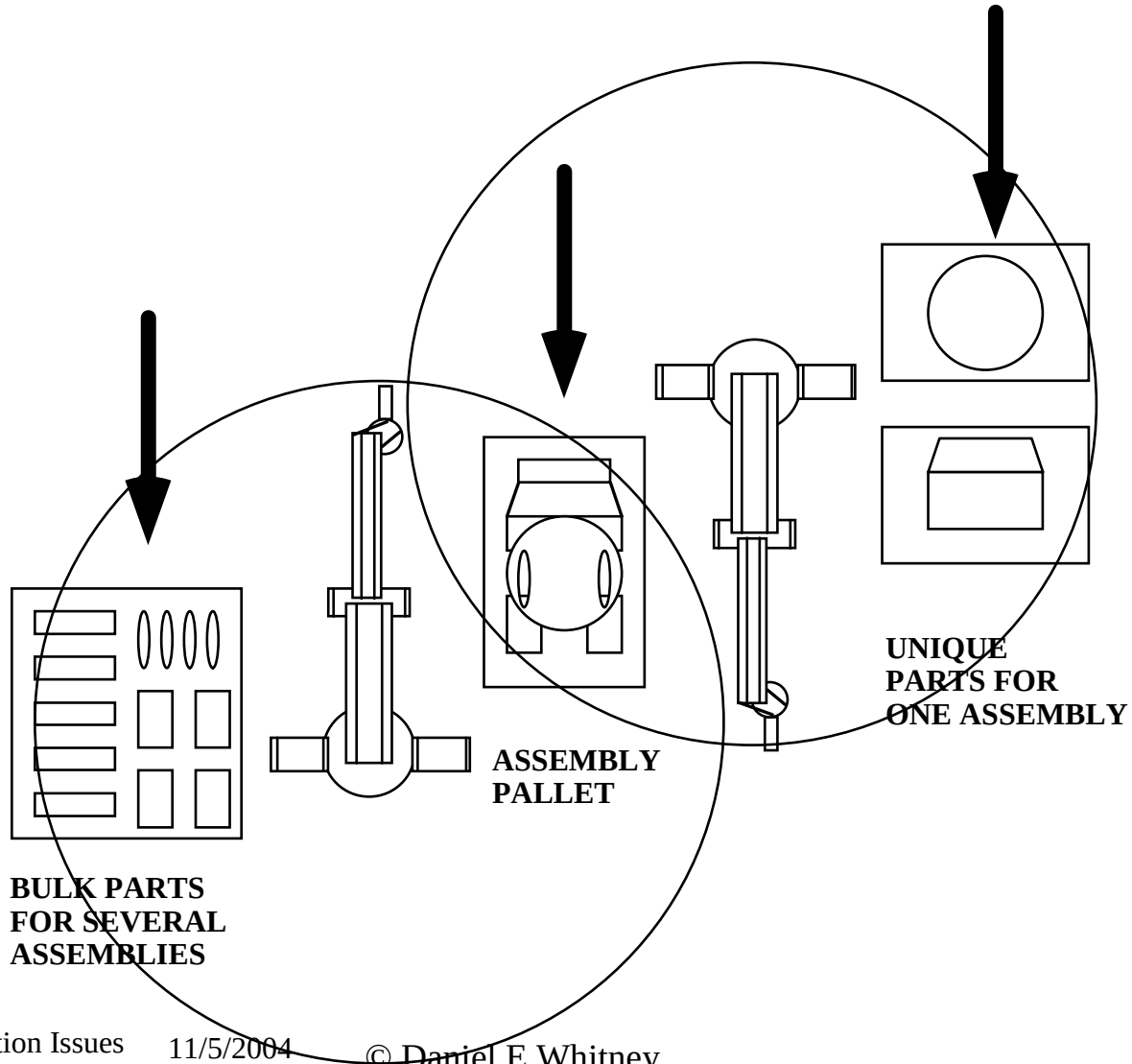
Source:
Figure 17-21(b) in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Pallet Arrangement for Large Parts



Starter Assembly Automation Line

(Slide from Denso)

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Source:
Figure 16-31 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Making Stacks - Method 1

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Source:
Figure 17-27 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Making Stacks - Method 2

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Source:
Figure 17-28 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Making Stacks - Method 3

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Source:
Figure 17-29 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

AMP Ignitor

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Source:
Figure 17-30 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Manual Assembly Sequence

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Source:
Figure 17-31 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Alternate Process

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Source:
Figure 17-32 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Alternate Process One-handed

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Source:
Figure 17-33 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Single Station System

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Source:
Figure 17-34 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.