JIT Flow Simulation
AKA: The “Paper Airplane” Exercise

This is a simple, but powerful, teaching tool that allows the demonstration of nearly every JIT principle and gives an opportunity to discuss the rest. The power is in the *flexibility* of the exercise to be adapted and modified to nearly any circumstance.

These instructions are not intended to be in any way prescriptive. They are, however, an effective and proven baseline from which to operate.

Required Number of Participants

Operators	4
Expediter/Material Handler	1
Factory Manager	1
Customer	1
Timers	2

Basic Exercise (45 - 60 minutes, use in SIM, most AIW situations)

Materials:

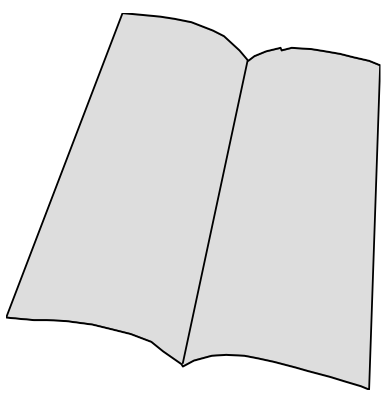
60 sheets plain paper
20 sheets 3 punch paper
10 sheets colored paper

2 stopwatches
1 calculator
flip chart
two contrasting color markers

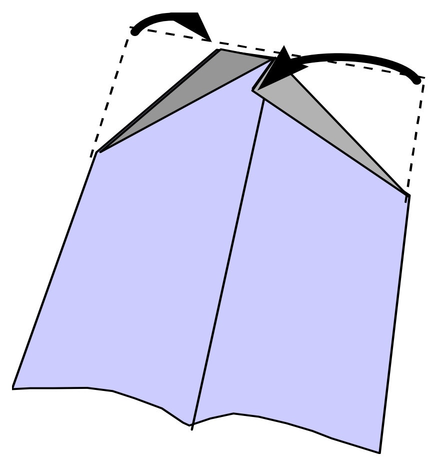
Preparation:

Pre-build four production station sets:

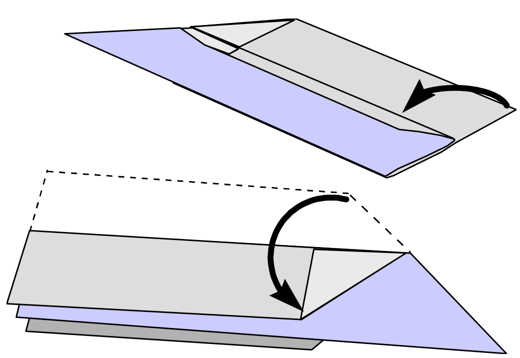
1. Two sheets plain (unfolded paper), one w/ fold #1.
2. Two sheets w/ fold #1; one with folds #1, #2.
3. Two sheets w/ fold #1, #2; one with folds #1, #2, #3.
4. Two with folds #1, #2, #3; one completed airplane.



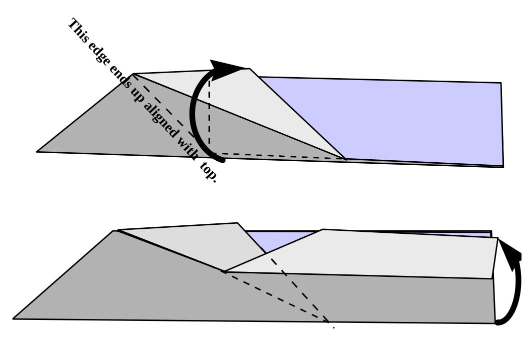
Fold #1 (Op #1)



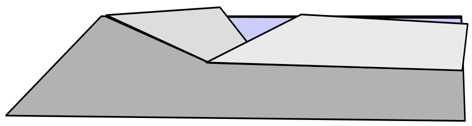
“Fold” #2 (Op #2)
(two folds)

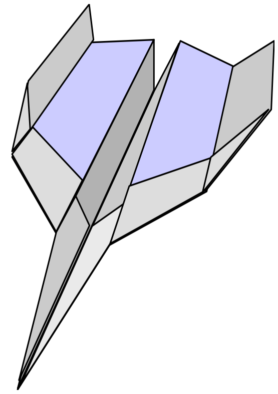


“Fold” #3 (Op #2)
(two folds)



“Fold” #4 (Op #4)
(two folds each side, four folds total)





Finished Plane

Note: As silly as it seems, there is a *reason* for the folds illustrated. Using this design ensures that there is a big enough work imbalance to make some important teaching points, especially in the “advanced variation” at the end of this document.

On a flip chart, draw the following matrix:

Lot Size			
WIP			
Throughput (Lead) Time			
Total Run Time			
Deliveries (to customer)			
# of people			
Space			
Productivity (Units / Person / Minute)			
Quality			
Comments, Observations			

Set up the exercise. This should be fun, not dry.

Run #1

Announce that we are going to demonstrate the differences between various production systems by setting up a factory that makes airplanes. Ad lib something about the airplanes we are making. (they don’t fly, etc.)

Ask for a volunteer for operator #1. Point out that this job requires some skill and precision. When someone volunteers, give them production station set #1. Make a flourish out of demonstrating how to fold the paper, ask if they understand, then ask them to practice on the remaining sheet. They should now have three completed sheets for Op #1.

Repeat the process for operators #2, #3, and #4. Be sure to solicit volunteers from different tables, preferably criss-crossing the room several times.

Solicit a volunteer to be the materials handler. A good technique if no one is forthcoming is to see if anyone is wearing athletic shoes and "volunteer" them. Explain to the material handler that his job is to move material "from operation 1 to operation 2; from operation 2 to operation 3, from operation 3 to operation 4 and from operation 4 to our customer."

The customer can either be another student volunteer or a co-instructor. There is some advantage to using a co-instructor as customer. There is less briefing involved and co-instructors are generally more willing to be a pain to the factory manager when their deliveries are late. Quietly brief the customer to take any but obviously misfolded airplanes, but to object loudly if any of the airplanes made from "defective material" should be delivered to him. Make sure the customer knows what "defective material" is. (Another good reason to use a co-instructor as customer.)

Appoint a factory manager. Make it clear that the factory manager's job is to "keep things running smoothly and keep the customer happy." Don't let the factory manager help out.

Timers: If you are using stopwatches, you can keep time yourself, or appoint people to do it.

Point out that because of the distance between operations, we are building and moving materials in lots of three airplanes. They can move any multiple of three that are ready, but lots of three must stay together. Tell the operators that once they have completed three parts, they are to call for the material handler to take their work to the next operation. They should not wait for the material handler, though. If they have work queued up, they need to keep working.

Announce that everyone else in the class is a "wastologist, someone schooled and studied in the science of waste." They are to identify specific examples from the "Closed mitt" list and write them down for the debrief.

Tell them that once the system is running smoothly you will introduce a different color sheet of paper to track how long it takes product to move through the system. They are to treat that sheet like any other.

The customer will take all of the airplanes they can build. You (the instructor) will supply raw material to the first operation.

Ask if there are any questions. Do not allow them to change the production layout, etc. Only answer questions about how the factory will operate.

Announce "Go!" and start the production run timer.

Be sure to feed paper to Op #1 as fast as he needs it. If the operator makes an "improvement" and starts folding three sheets at a time, praise him for his improvement, but don't mention it unless he thinks of it.

Operation #2 and operation #4 should back up fairly quickly. Once there is significant WIP backed up in the system, introduce the colored sheet of paper. Start the throughput (lead) time timer as soon as the operator touches the stack.

At this point, the customer should begin bothering the manager about when the colored airplane will be delivered. (This is to point out schedule stability later.)

Start slipping "defective" raw material into the stack. If operator #1 is folding three at a time, start by sandwiching the defective material between two good sheets, then intermix stacks with no defects, one, two, or three defects. If the operator says something *try* to not respond at all - sometimes their comments are just to someone else at the table. If they get the factory manager or attempt to stop production, tell them that's the material you have. Try to keep it as low-key as possible.

(Note: An alternative for "defective material" is to take a stack of paper, drive a staple through one corner and pull it out. This leaves *very* subtle defects.)

At some point the students usually start expediting the colored airplane. Let them, but insist it always move as part of a group of three units. If they *do* expedite, let them. It's a good teaching point later.

When the customer gets the colored airplane, stop the exercise, and note the flow time for the colored plane.

Debrief

(Chart filled in with example, but typical, numbers. Obviously you use the "real" ones.)

	Run #1		
Lot Size	3		
WIP	32		
Total Run Time	7:15		
Throughput (Lead) Time	6:32		
Deliveries (to customer)	18		
# of people	6		
Space	4 tables		
Productivity	0.42		
Quality	12		
Comments, Observations			

Fill in "Run #1" at the top. "Our lot size was three" Ask everyone to count up how much WIP they have. Don't count delivered airplanes or raw material. Total it up and enter the number in WIP. If it doesn't divide by 3, have some fun about how THAT could happen.

Ask the timer (or announce if you kept time yourself) how long it took the colored airplane to flow through the system. If they expedited the colored plane, point out that this is the *expedited* time!

Ask the customer how many airplanes were delivered.

Remind the class that we had four operators, a material handler and a manager for a total of six people.

Say "we used four tables, so that's good for the space" and write '4' in the space box.

Calculate productivity. Tell the class we will measure productivity as "planes per person per minute." Divide the number of planes delivered to the customer by six (people). Divide that result by the *total start to finish* time of the exercise. This number is typically between 0.3 and 0.5.

Note: For calculation ease - six seconds = 0.1 minutes.
:06 seconds = 0.1 minutes
:12 seconds = 0.2 minutes
:15 seconds = 0.25 minutes
:30 seconds = 0.5 minutes
:45 seconds = 0.75 minutes

Ask permission from the class to round the minutes for calculation so they know what you are doing when the numbers look different.

Ask about quality. Hold up a piece of "defective material" and ask how many pieces are in the system. The class will have to go through a mad search to locate and find the pieces with defective material. Point out how much time and effort they are spending and ask them how often they go through this exercise in real life when they discover a problem. Write the number of defects in the box.

Ask everyone "What was it like to work here?" Try to facilitate the group through understanding: Stress, chaos, no communication, didn't know how much work to do, etc. Ask the "wastologists" what they observed, record their comments on the flip chart.

Ask them where the bottleneck is in the process. Most will agree it is either operation #2, operation #4 or both.

Run #2

Ask the class what we can do to fix some of the problems.
They will nearly always suggest putting the operations closer together.

Clear off a table (if you haven't done so already), and seat the operators around it in order. (Preferably with production going counter-clockwise if the table permits.) Seat the customer next to operation #4. Tell the material handler that he will be kept on the payroll and moved to another job.

Ask the rest of the class to gather around so they can see what is happening.

Ask what would happen to the WIP levels if we just ran the exercise again? You may have to lead them through understanding that they would rapidly build up again (maybe more rapidly) and the total lead times probably wouldn't be much better.

To avoid that problem, some system has to be put in place to manage how much WIP is allowed to build up in the line. We are going to use a pull system to regulate each station's production.

Place a sticky-note between each person at the table.

Explain the role of the "kanban square" as a means to regulate overproduction - the worst of the ten wastes.

Each operator LOOKS RIGHT, and if there is no WIP on that square, pulls work in FROM THE LEFT.

Tell the customer NOT to take any planes from the square, and have the operators practice the kanban rules by building. As the planes work their way around, watch operator #1 and #2. Their pace will be slowed when Operator #4 gets the first plane. They will be tempted to pull work in early. Stop them!

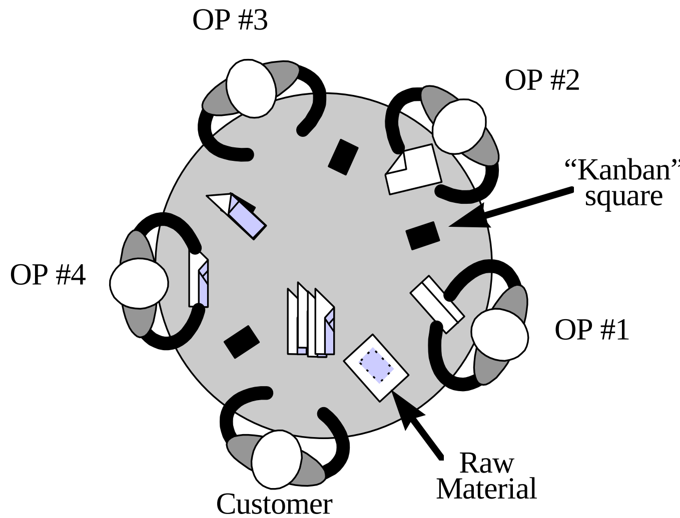
When the customer's kanban gets the first plane, all work should stop.

Start the exercise by having the customer pull the plane off the kanban, start the elapsed time.

After they have established a rhythm (six or seven minimum planes to the customer), introduce the colored sheet and start the lead-time timer.

Stop the exercise when the customer pulls the colored airplane off the last kanban. Stop both timers.

Focus the attention of the class back to the chart at the front and begin collecting the statistics.
Sample Data - Your Mileage May Vary



	Run #1	Run #2	Delta
Lot Size	3	1	
WIP	32	4	
Throughput (Lead) Time	6:32	1:12	
Total Run Time	7.15	1:65	
Deliveries (to customer)	18	10	
# of people	6	5	
Space	4 tables	1 table	
Productivity	0.42	1.21 (.85)	
Quality	12		
Comments, Observations			

Ask how much WIP is on the table (not raw material, not customer delivered planes). It will be 3 or 4. Ask the MAXIMUM WIP level that will ever develop in this system. (4). Ask what is the maximum WIP level that could develop in the "traditional" (Run #1) system - infinite - there is no WIP management.

Record the measured throughput time. Ask how long another plane will take? (Same). Ask how long EVERY plane will take. (Same). How about the first run? Remember - they probably *expedited* that one. How long does it take? (No one knows, and it varies with the amount of WIP in the system.) <u>Lead time is directly related to the amount of WIP in the queues. If WIP isn't regulated, there is *no way* to predict flow time for a particular item.</u>

Point out that the material handler's job is no longer required here, and the manager's job is significantly reduced because there is less intervention to do. The manager can spend more time and attention on improvements and prevention and less on fighting fires.

Calculate productivity the same way as above. It will be significantly higher. Calculate the productivity again, *using six people*. It is STILL higher about 80% of the time. This proves that the productivity gain wasn't just in eliminating the person from the loop.

Ask about quality. Hypothetically, if the "bad material" had found its way all the way to the customer, what is the *worst case* for defects? (4). In the *worst case*, how long until the system can start delivering again once it starts up? (lead time, in this example, one minute, twelve seconds.) What about the first case? Not sure.

Ask about the differences in the working environment.
(Less stress, better communication, etc.)

Ask the wastologists what they saw. They should have spotted the fact that most operators were spending a lot of time waiting in this case, where they were busy in the first case.

Ask if their work statement has changed. (No). The point is - <u>When the chaos and queues are cleared out, it is easier to see what is happening</u>. The work imbalance existed in both cases, but now the bottleneck (Op #4) is obvious.

What to do about it depends on whether the system was meeting customer demand or not. If it was delivering fast enough, then improvement activity should focus on combining operations in the first three ops rather than taking work away from #4.

Point out that without knowing customer requirements, it is impossible to determine what improvement activity is necessary. This is a segue into *takt time* and work balancing in the Continuous Flow material.

See “Advanced Variation” to make these last points more effectively.

Advanced Variation - Takt Time and Work Balance

During Run #1 observe Operator #4. *If he is taking significantly longer than 15 seconds to do his folds, you will have to modify the presentation to start with doing improvement activity on Operation #4 before immediately redistributing the work.*

When setting up Run #2, explain that the customer's true requirement is one plane every 15 seconds. Explain that this is called the *takt time*, and reflects the customer's rate of consumption. Instruct the customer to take an airplane no more often than once every 15 seconds and give her a watch with a second hand if she doesn't already have one.

Do Run #2 as outlined above only with the takt time restriction.

Covertly calculate the RATE OF PRODUCTION from Run #1. (Planes Delivered / Total Elapsed Time) This is typically about 3/minute. I have never had it exceed, or even meet, 4/ minute.

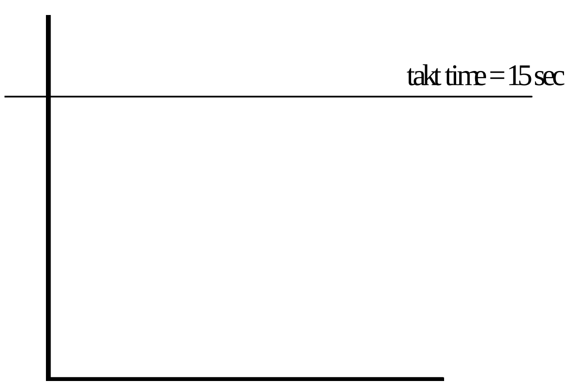
During the outbrief:

Go through the same metrics as above.

Ask about the bottleneck. Most people will begin to suggest leveling the work to reduce operator #4's workload.

Point out that, based on the customer's true requirements, Operator #4 kept up and does not need to work faster.

Ask, again, what would the next improvement activity be?
(Usually a rhetorical question on your part - there is rarely an answer that isn't grasping for something.)

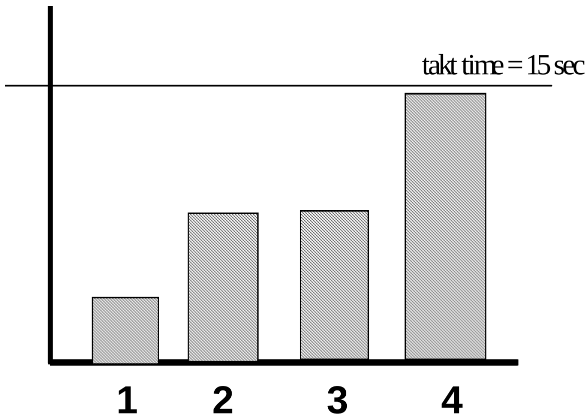


Explain the work balance chart as you draw it on the flip chart. Use a different color (red) for the takt time line.

Explain that, because of exhaustive data collection, we know the *cycle times* for each operation in the paper plan factory. They are:

Op #1	3-4 seconds
Op #2	7-8 seconds
Op #3	7-8 seconds
Op #4	12-15 seconds

Point out that *only by knowing this information and the takt time* can management make a good decision about how to improve performance.

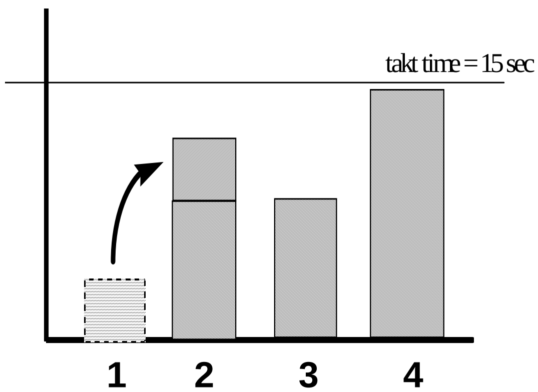


Add bars reflecting the cycle times to the chart.

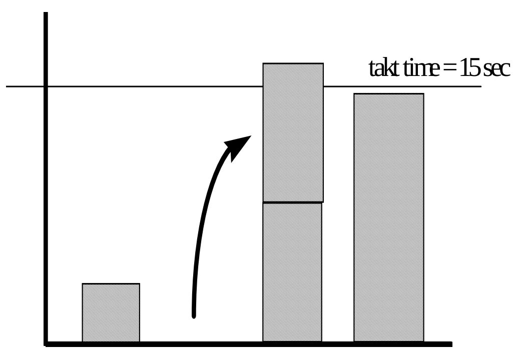
Ask again, where should we improve?

Many people will still want to level-load operations 1, 2, 3 and sometimes all of them.

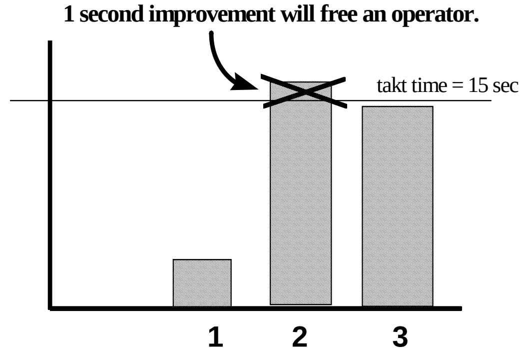
Others will suggest combining operation 1 with operation 2.

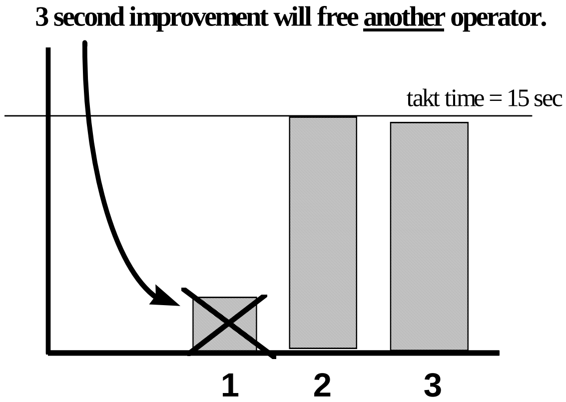


Point out that while that would free up another operator, it would require major work to make further improvements.



Point out that if Operation 2 and 3 total less than the takt time that we could reallocate another operator and improve productivity by another 25%. If it was close, as illustrated here, it would require only a very small improvement in the cycle time to get the benefit.





That leaves us with operator #1 with three seconds of work. If we can somehow improve the process and remove three more seconds, that would let us build to the customer's requirement with two operators, not four.

Only by thoroughly understanding the cycle times and the takt time is it possible to see the resources that are *really* required to meet the customer's requirement. Without that information, we are managing blind.

What would be the consequences if people who didn't look busy all of the time were told to "get to work?"

We would never see the idle time that is available, and would assume we needed more capacity, when in reality, there is too much. *We would never see that by saving a total of <u>four seconds</u> from the combined cycle times we can reallocate 50% of the operators*.

By making sure people "stay busy" you are depriving yourself of information you <u>must have</u> to make rational management decisions.

Takt time is one of the most powerful management tools available, and is the heart of managing a JIT production system.