Detailed Design For Assembly Guidelines

1. **Simplify the design and reduce the number of parts** because for each part, there is an opportunity for a defective part and an assembly error. The probability of a perfect product goes down exponentially as the number of parts increases. As the number of parts goes up, the total cost of fabricating and assembling the product goes up. Automation becomes more difficult and more expensive when more parts are handled and processed. Costs related to purchasing, stocking, and servicing also go down as the number of parts are reduced. Inventory and work-in-process levels will go down with fewer parts. As the product structure and required operations are simplified, fewer fabrication and assembly steps are required, manufacturing processes can be integrated and leadtimes further reduced. The designer should go through the assembly part by part and evaluate whether the part can be eliminated, combined with another part, or the function can be performed in another way. To determine the theoretical minimum number of parts, ask the following: Does the part move relative to all other moving parts? Must the part absolutely be of a different material from the other parts? Must the part be different to allow possible disassembly?

2. **Standardize and use common parts and materials** to facilitate design activities, to minimize the amount of inventory in the system, and to standardize handling and assembly operations. Common parts will result in lower inventories, reduced costs and higher quality. Operator learning is simplified and there is a greater opportunity for automation as the result of higher production volumes and operation standardization. Limit exotic or unique components because suppliers are less likely to compete on quality or cost for these components. The classification and retrieval capabilities of product data management (PDM) systems and component supplier management (CSM) systems can be utilized by designers to facilitate retrieval of similar designs and material catalogs or approved parts lists can serve as references for common purchased and stocked parts.

3. **Design for ease of fabrication**. Select processes compatible with the materials and production volumes. Select materials compatible with production processes and that minimize processing time while meeting functional requirements. Avoid unnecessary part features because they involve extra processing effort and/or more complex tooling. Apply specific guidelines appropriate for the fabrication process such as the following guidelines for machinability:

   For higher volume parts, consider castings or stampings to reduce machining
   Use near net shapes for molded and forged parts to minimize machining and processing effort.
   Design for ease of fixturing by providing large solid mounting surface & parallel clamping surfaces

Avoid designs requiring sharp corners or points in cutting tools - they break easier
Avoid thin walls, thin webs, deep pockets or deep holes to withstand clamping & machining without distortion
Avoid tapers & contours as much as possible in favor of rectangular shapes
Avoid undercuts which require special operations & tools
Avoid hardened or difficult machined materials unless essential to requirements
Put machined surfaces on same plane or with same diameter to minimize number of operations
Design workpieces to use standard cutters, drill bit sizes or other tools
Avoid small holes (drill bit breakage greater) & length to diameter ratio > 3 (chip clearance & straightness deviation)

3. **Design within process capabilities and avoid unneeded surface finish requirements.** Know the production process capabilities of equipment and establish controlled processes. Avoid unnecessarily tight tolerances that are beyond the natural capability of the manufacturing processes. Otherwise, this will require that parts be inspected or screened for acceptability. Determine when new production process capabilities are needed early to allow sufficient time to determine optimal process parameters and establish a controlled process. Also, avoid tight tolerances on multiple, connected parts. Tolerances on connected parts will "stack-up" making maintenance of overall product tolerance difficult. Design in the center of a component's parameter range to improve reliability and limit the range of variance around the parameter objective. Surface finish requirements likewise may be established based on standard practices and may be applied to interior surfaces resulting in additional costs where these requirements may not be needed.

4. **Mistake-proof product design and assembly** (poka-yoke) so that the assembly process is unambiguous. Components should be designed so that they can only be assembled in one way; they cannot be reversed. Notches, asymmetrical holes and stops can be used to mistake-proof the assembly process. Design verifiability into the product and its components. For mechanical products, verifiability can be achieved with simple go/no-go tools in the form of notches or natural stopping points. Products should be designed to avoid or simplify adjustments. Electronic products can be designed to contain self-test and/or diagnostic capabilities. Of course, the additional cost of building in diagnostics must be weighed against the advantages.

5. **Design for parts orientation and handling** to minimize non-value-added manual effort and ambiguity in orienting and merging parts. Basic principles to facilitate parts handling and orienting are:
Parts must be designed to consistently orient themselves when fed into a process.
Product design must avoid parts which can become tangled, wedged or disoriented. Avoid holes and tabs and designed "closed" parts. This type of design will allow the use of automation in parts handling and assembly such as vibratory bowls, tubes, magazines, etc.

- Part design should incorporate symmetry around both axes of insertion wherever possible. Where parts cannot be symmetrical, the asymmetry should be emphasized to assure correct insertion or easily identifiable feature should be provided.
- With hidden features that require a particular orientation, provide an external feature or guide surface to correctly orient the part.
- Guide surfaces should be provided to facilitate insertion.
- Parts should be designed with surfaces so that they can be easily grasped, placed and fixtured. Ideally this means flat, parallel surfaces that would allow a part to picked-up by a person or a gripper with a pick and place robot and then easily fixtured.
- Minimize thin, flat parts that are more difficult to pick up. Avoid very small parts that are difficult to pick-up or require a tool such as a tweezers to pick-up. This will increase handling and orientation time.
- Avoid parts with sharp edges, burrs or points. These parts can injure workers or customers, they require more careful handling, they can damage product finishes, and they may be more susceptible to damage themselves if the sharp edge is an intended feature.
- Avoid parts that can be easily damaged or broken.
- Avoid parts that are sticky or slippery (thin oily plates, oily parts, adhesive backed parts, small plastic parts with smooth surfaces, etc.).
- Avoid heavy parts that will increase worker fatigue, increase risk of worker injury, and slow the assembly process.
- Design the work station area to minimize the distance to access and move a part.
- When purchasing components, consider acquiring materials already oriented in magazines, bands, tape, or strips.

6. **Minimize flexible parts and interconnections**. Avoid flexible and flimsy parts such as belts, gaskets, tubing, cables and wire harnesses. Their flexibility makes material handling and assembly more difficult and these parts are more susceptible to damage. Use plug-in boards and backplanes to minimize wire harnesses. Where harnesses are used, consider foolproofing electrical connectors by using unique connectors to avoid connectors being mis-connected. Interconnections such as wire harnesses, hydraulic lines, piping, etc. are expensive to fabricate, assemble and service. Partition the product to minimize interconnections between modules and co-locate related modules to minimize routing of interconnections.

7. **Design for ease of assembly** by utilizing simple patterns of movement and minimizing the axes of assembly. Complex orientation and assembly movements in various directions should be avoided. Part features should be provided such as chamfers and tapers. The product's design should enable assembly to begin with a base component with a large relative mass and a low center of gravity upon which other parts are added. Assembly should proceed vertically with other parts added on top and positioned with the aid of gravity. This will minimize the need to re-orient the assembly and reduce the need for temporary fastening and more

complex fixturing. A product that is easy to assemble manually will be easily assembled with automation. Assembly that is automated will be more uniform, more reliable, and of a higher quality.

8. **Design for efficient joining and fastening**. Threaded fasteners (screws, bolts, nuts and washers) are time-consuming to assemble and difficult to automate. Where they must be used, standardize to minimize variety and use fasteners such as self threading screws and captured washers. Consider the use of integral attachment methods (snap-fit). Evaluate other bonding techniques with adhesives. Match fastening techniques to materials, product functional requirements, and disassembly/servicing requirements.

10. **Design modular products** to facilitate assembly with building block components and subassemblies. This modular or building block design should minimize the number of part or assembly variants early in the manufacturing process while allowing for greater product variation late in the process during final assembly. This approach minimizes the total number of items to be manufactured, thereby reducing inventory and improving quality. Modules can be manufactured and tested before final assembly. The short final assembly leadtime can result in a wide variety of products being made to a customer's order in a short period of time without having to stock a significant level of inventory. Production of standard modules can be leveled and repetitive schedules established.

11. **Design for automated production.** Automated production involves less flexibility than manual production. The product must be designed in a way that can be more handled with automation. There are two automation approaches: flexible robotic assembly and high speed automated assembly. Considerations with flexible robotic assembly are: design parts to utilize standard gripper and avoid gripper / tool change, use self-locating parts, use simple parts presentation devices, and avoid the need to secure or clamp parts. Considerations with high speed automated assembly are: use a minimum of parts or standard parts for minimum of feeding bowls, etc., use closed parts (no projections, holes or slots) to avoid tangling, consider the potential for multi-axis assembly to speed the assembly cycle time, and use pre-oriented parts.

12. **Design printed circuit boards for assembly**. With printed circuit boards (PCB's), guidelines include: minimizing component variety, standardizing component packaging, using auto-insertable or placeable components, using a common component orientation and component placement to minimize soldering "shadows", selecting component and trace width that is within the process capability, using appropriate pad and trace configuration and spacing to assure good solder joints and avoid bridging, using standard board and panel sizes, using tooling holes, establishing minimum borders, and avoiding or minimizing adjustments.