Chapter 9.03

**Suss Microtech FC150 Flip Chip Bonder**

(flipchip - 382)

1.0 **Title**

FC150 Flip Chip Bonder

2.0 **Purpose**

*Note:* The FC150 is a complex system that requires proper, thorough training before actual use. Prospective Users are obligated to carefully study this manual before receiving any hands-on training. All training is currently performed by Matthew Wasilik. Contact Matthew directly to set up a training session <<mwasilik at eecs.berkeley.edu>>.

The FC150 flip chip bonder is a precision instrument used to align and bond one or more chips onto a substrate using pressure and/or heat. The current configuration of the system allows the following flip chip techniques: solder reflow, thermocompression, and cold compression bonding of die-size substrates. By default the system is configured for use with UBA (Universal Bonding Arm) thermocompression. Post-bond alignment tolerance specs for UBA processing are 3 micron or better (after proper calibration has been performed).

3.0 **Scope**

This manual describes alignment, programming, and operating procedures pertaining to the FC150.

4.0 **Applicable Documents**

**Revision History**

4.1 **Silicon Carbide Tooling Drawings**

(see Table 2 for Tooling Load Capacities)

4.1.1 6-inch chuck

4.1.2 Pedestal tool #1

4.1.3 Micro pickup tool

*Note:* The maximum allowable force that the Micro pickup tool will tolerate is 1 kg. DO NOT attempt to submit this tool to forces > 1 k

4.1.4 Calibration tool

4.1.5 Pedestal tool #2

5.0 **Definitions & Process Terminology**

(Figures 1 and 2 serve as visual supplements to this section)

5.1 **Advanced Laser Leveling:** This refers to an option that uses a laser to level the chuck and arm instead of the autocollimator. *NEVER* attempt to adjust the laser leveling knobs! They are factory preset and doing so will result in loss of the beam.

5.2 **Autocollimator:** Optical device used to help make chuck and arm (chip and substrate) parallel to one another.
5.3 **UBA:** Universal Bonding Arm. Designed for a wide range of applications. The UBA has the capacity to apply a force up to 50 kg. A built-in infrared profiled heating system quickly heats the chip to 450ºC. The UBA has the capability to operate in thermocompression mode or solder reflow mode with Z control.

5.4 **SRA:** Solder Reflow Arm. The SRA provides a low contact force, adjustable from 30 to 200 grams. The SRA is fitted on a vertical stage, capable of high Z-axis resolution down to 1 micron. The SRA also incorporates Infrared heating for the chip.

5.5 **Chuck:** The current default 6-inch chuck is configured for high force use. The chuck accommodates 6-inch, 5-inch, 4-inch, and die size substrates. The default vacuum groove is for die size. If a larger size substrate is to be used contact staff, as the proper vacuum channels must be first properly oriented. The chuck is capable of withstanding 50 kg of force from the UBA. **However, DO NOT press on the chuck!** Delicate parts contained within the chuck mechanism (Zerodur® thermode) can easily be broken by hand. The chuck position itself is preset by staff, and should not be adjusted by qualified labmembers. Great care should be taken whenever positioning substrates manually upon the chuck.

5.6 **Substrate:** This refers to the die or device to be bonded that is secured on the chuck (lower part).

5.7 **Chip:** This refers to the die or device to be bonded that the arm (either UBA or SRA) secures (upper part).

5.8 **Waffle Pack:** A chip/substrate tray that contains separate compartments for each die. Each tray typically has a cavity fitted to the die that allows for easy loading and unloading, and prevents rotation.

5.9 **Chip Cassette:** A waffle pack for chip(s). Nanolab’s FC150 is equipped with 6 different 2-inch chip cassette holders located to the left of the chuck.

5.10 **Substrate Cassette:** A waffle pack for substrates(s). Nanolab’s FC150 is equipped with 2 different 4-inch substrate cassette holders located to the right of the chuck.

5.11 **High Resolution XY Stage:** The Nanolab FC150 has this option installed. The high-resolution stage can move in increments of 0.1 µm.

5.12 **Tooling:** This typically refers to precision manufactured silicon carbide chip and substrate holders that are secured via vacuum to the arm and chuck respectively. Each tool requires custom fabrication, and should be handled, only if necessary, with EXTREME care.

5.13 **Tooling Magazine:** Nanolab’s FC150 is equipped with 5 different slots available for SiC tooling. Slots are labeled A, B, C, D and E from the left to right respectively. This is referred to as a tooling magazine, and it is located just behind the chuck.

5.14 **Quartz Test Die:** vernier patterned quartz test dies used for testing the alignment accuracy of the system.

5.15 **Chip Flipper:** The Nanolab FC150 has this option installed. The chip flipper is a component that essentially picks up a die from the chip cassette, “flips” it over 180°, and then allows the arm to acquire it.

5.16 **Process Recording:** The Nanolab FC150 has this option installed as well. Process recording allows the User to track and log actual process parameters in real time. These parameter values can also be saved to a file.

5.17 **Thermode:** The silicon carbide tooling for the substrate and chip rest upon the thermodes. The thermodes are made of the ceramic Zerodur®, an extremely low thermal expansion material. It is highly important to be very careful when changing SiC tooling by hand, so as not to chip, scratch, or otherwise harm the thermodes!
6.0 **Safety**

Follow general safety guidelines in the lab as well as the specific following safety rules when working with the FC150.

6.1 **Electrical Hazard:** The FC150 utilizes **high electric power** (high amperages) to heat its elements. **NEVER** attempt to remove the side panels or encroach the system from the rear panel via the service chase as this is considered a danger zone.

6.2 **Physical Hazard:** **NEVER** place fingers between the XY stage and the granite base. If the air pressure fails and the air bags are deflated, serious injuries could result.

6.3 **Burn Hazard:** The heating elements in the FC150 can reach 450ºC. The access door should always be closed and locked during heating. Users should **NEVER** attempt to open the door when heating is taking place.

6.4 **Moving Parts:** The access door **automatically locks closed** with a solenoid bolt (located at the top of door) when stages or arms are in motion, or elements are heating. **DO NOT** attempt to open the door when door is locked!

6.5 **Safety Glasses:** Safety glasses should be worn at all times when working with the FC150.

6.6 **Emergency Stop Button:** Red button located on front-left panel of tool. Pressing this button will cut power to the entire system. Use this button **only** if person or equipment is in harm’s way - e.g. earthquake, fire, severe coolant leak, or for any other dire circumstance.

7.0 **Statistical Process Control**

N/A

8.0 **Available Process, Gases, Process Notes**

8.1 **SRA Processing:** The solder reflow arm is capable of reflowing at 450ºC, with a maximum force of 0.25 Newtons.

8.2 **UBA Processing:** The UBA (Universal Bonding Arm) is used for thermo-compression processing. 50kg of compressive force is possible with a max temperature of 450ºC.

8.3 **Polymer Stud Bump:** A T5000 rotary displacement pump will be available for use with the FC150 system shortly. This will make accurate polymer stud bump placement possible. For more information regarding such a process please contact Matthew Wasilik.

8.4 **Hot Embossing:** The FC150 has the capability to perform hot embossing for certain nano imprint applications. Contact staff for details.

9.0 **FC150 Flip Chip Operation**

Operation of the FC150 can be divided into four different basic steps: loading, alignment, bonding, and unloading. Loading and unloading are controlled by the pre-programmed information contained in the template libraries. Bonding is controlled by the pre-programmed information contained in the bonding library. Alignment is typically performed by the User, but there is also an option to use the pattern recognition system option that is configured with the tool. The pattern recognition software (COGNEX) will not be discussed in this manual. For details on COGNEX software, contact staff. Overall control of the specific template and bonding libraries is provided by User-written macro programs via a simplified programming window.

If at any time a chip, substrate or any other object falls into the stage or onto the granite slab where the stage moves, immediately stop use of the tool and retrieve it. Make sure to avoid contacting the needle valves when retrieving samples fallen into the stage area. If you are unable to retrieve your fallen items completely and/or safely, discontinue the use of the tool and contact Nanolab Staff.
9.1 **System Prep**

9.1.1 Enable flipchip on Mercury.

9.1.2 Turn on GLI2540-10 power supply for microscope illumination.

9.1.3 Turn power to monitor ON.

9.2 **System Reset**

By default there is no setup information stored in the system. As a precaution, a reset should thus always be performed as the first step when using the FC150. Also, a system reset is required after any error has occurred. However:

*NEVER perform a system reset if there is tooling on the arm!!!*

Failure to adhere to this important rule may result in broken tooling. If during a process a system error is encountered while tooling is on the arm, simply walk away from the equipment and report a fault on the Mercury.

9.2.1 After logging in to the FC150 system software, ensure that the main door is closed. Use the mouse (trackball) to select the Reset button on the FC150 Manager menu. The system should respond by homing each axis.

9.2.2 During resetting, the reset message box appears on the screen for approximately one minute. Wait until this window has disappeared to continue.

9.3 **SRA Configuration and Calibration**

By default, the FC150 is configured for use with the UBA. SRA processing typically implies a need for delicate, high alignment accuracy. To have the system configured for SRA processing, email a request to flipchip at silicon. An SRA calibration will be performed by staff following reconfiguration. Such is necessary prior to a critical alignment and bonding process. The standard SRA calibration involves substrate-to-chip parallelism, microscope, and autocollimator adjustments.

9.4 **UBA Calibration**

Again, the UBA is by default configured for use with the FC150 system. A calibration prior to critical alignment and bonding is necessary to maintain high accuracy. Staff will handle all calibration procedures for the UBA. Send a written request to flipchip at silicon in order to have a calibration performed. The standard UBA calibration involves substrate-to-chip parallelism, microscope, and autocollimator adjustments.

9.5 **Cassette Library**

The Cassette library refers to the location of the chip(s) in the chip “wafflepack”. The cassette parameters are arranged in records in the cassette library. Each different cassette template has its own record within the library. The user enters the name of each record, which is then used when creating a new bonding cycle. The cassette library application allows the user to create and modify these templates, as well as storing them in memory. The three types of cassette that can be defined by the user are custom, matrix, or multiple.

9.5.1 Select **Cassette** from the Libraries menu.

9.5.2 Select **Open** to view a currently existing cassette definition. Select **New** to create a cassette definition. A new cassette definition will require input on the location of the chip/substrate, the chip/substrate dimensions, and the tool location (A, B, C, etc.) to be used for chip pick-up.
9.6 Substrate Library
The substrate library refers to the location of the substrate die(s) in the substrate “wafflepack”. Substrate parameters are arranged in records in the substrate library. Each different substrate template has its own record within the library. The user enters the name of each record, which is then used when creating a new bonding cycle. The substrate library application allows the user to create and modify these templates as well as store them in memory.

9.6.1 Select Substrate from the Libraries menu
9.6.2 Select Open to view a currently existing substrate definition. Select New to create a substrate definition. A new substrate definition will require input about bonding site positions, alignment mark positions, and layout.

9.7 Reflow Library
Solder reflow (RF) consists of bonding the chip onto the substrate using the solder bumps which melt when the temp of the chip and or substrate is increased to above the melting or eutectic point.

9.7.1 Select Reflow from the Libraries menu.
9.7.2 The library allows the User to define heating parameters and Z arm values during a reflow-type bonding process.

9.8 IR Thermocompression Library
Infrared thermocompression (IR) uses pressure and heat to bond a chip to a substrate. Note that the UV thermocompression library is not used with current system configuration.

9.8.1 Select IR Thermocompression from the Libraries menu.
9.8.2 The library allows the User to define heating parameters and Z arm values during a reflow-type bonding process.

9.9 Programming a Cycle
Users have the ability to write custom bonding cycles on the FC150 system. Cycles are programmed in Pascal, but this is made easy via specific visual point-and-click macros in the FC150 software.

9.9.1 Select the Edit button on the manager menu. A window should appear that allows Users to write a bonding cycle. Other editing windows can be opened and closed as required.

9.9.2 Select the Outline button (or can select “outline” under the options menu). This function of the system allows the user to write customized cycles using the standard Windows interface. When an instruction is selected, a dialogue box automatically appears requesting the relevant parameters. Enter the parameter(s), then select OK to validate. It is strongly recommended that comments be used in the program to make it easier to understand or modify at a later time. Comments must be placed between brackets {}. They can be inserted anywhere in the program.

9.9.3 In addition to Pascal functions, a STEPBYSTEP variable is available for use in a programming cycle. Inclusion in a cycle allows the execution to occur one step at a time, further prompting the User to continue or abort.

9.9.4 Before a cycle may be executed, it must be compiled. Select Compile from the cycles menu. If an error is found during compilation, a special window will be created listing the errors found. Select Output (Comp) from the cycles menu to view this window.

9.10 Manual Operation of Functions
9.10.1 It is critical that manual operation be used with great care! Failure to understand precisely what a specific manual function command does may result in damage to the tool! If User
is not sure of a function’s operation, do not attempt to execute! If at any time a chip, substrate or any other object falls into the stage or onto the granite slab where the stage moves, immediately stop use of the tool and retrieve it. Make sure to avoid contacting the needle valves when retrieving samples fallen into the stage area. If you are unable to retrieve your fallen items completely and/or safely, discontinue the use of the tool and contact Nanolab Staff.

9.10.2 To verify individual functions with the tool (perhaps when writing a cycle), select Manual from the cycles menu. The appearing window is essentially the same as the outline window, save for the difference that one has to set the cassette and substrate definitions. After changing a cassette or substrate name, remember to click the Set Cassette or Set Substrate button as appropriate. Clicking the Execute button will run the selected function: Again, be sure that the selected function is actually intended before selecting Execute!!!

9.11 Running a Cycle

9.11.1 Ensure all tooling, cassettes, chips, and substrates are carefully placed as appropriate with regards to what the specific cycle program expects.

9.11.2 Ensure that the GLI2540-10 optics lamp in ON such that chips and substrates may be illuminated for alignment purposes. Note that by default this lamp is kept switched OFF.

9.11.3 Select desired cycle from the cycles menu

9.11.4 Next select the Run button to run the cycle selected.

9.11.5 After the cycle has been completed, all personal tooling should be removed from the tool magazine, chips, substrates, and waffle packs should be removed, and the optics lamp should be turned OFF.

9.12 Alignment

The alignment phase is one of the most important for the User. Under this phase almost all parts of the system are under the User’s control. Refer to Figure 3 for visual supplement to this section.

When entering the alignment phase, the alignment sequence window opens. Use the left joystick to focus on the chip and substrate, and move the microscope. Use the right joystick to move the chuck in the x and y directions.

Multiple functions can be used when performing an alignment to make it more convenient for the User. These function options are located in alignment sequence window, and may be chosen by selecting the appropriate function key. They include set origin, chuck return, optics return, and the indexing of the optics stage and chuck. The Unlock/Lock Door function may be used when it is necessary to reorient substrate. NOTE: Take care to NOT press on chuck when positioning substrate manually! Some components of the chuck are delicate, and may EASILY be broken if great care is not taken! When the Autocollimate function (F7) is selected from the alignment sequence window, a message box asks if the User wishes to use manual leveling or laser leveling. Laser leveling is used to level the chip and substrate when there is not enough reflection from them to use the autocollimator. An algorithm in the software then calculates the angular correction necessary to carry out the leveling. The View Chip and Substrate function allows the User to superimpose the chip and substrate images. The function key F10 may be continuously toggled to show the chip, the substrate, or both images.

Note that although the following section specifically describes the procedure for an alignment accuracy placement calibration, the same basic steps are typically used for an actual chip-substrate alignment.
Alignment Accuracy Calibration

9.12.1.1 Begin by cleaning the two 12mm quartz test dies thoroughly. Use IPA and tech wipes. Blow dry with N2 gun. Use care! Do not to drop, chip, or scratch, the test dies are expensive!

9.12.1.2 The quartz test dies may now be placed in the Test cassettes. Place die in default TestKSF2 chip cassette such that chrome is face down. Place other die in default TestKSF4 substrate cassette such that chrome is face up. Ensure that test die reference marks are in same corner for both chip and substrate dies.

9.12.1.3 Ensure both substrate and chip cassettes are placed in upper right corner positions.

9.12.1.4 Ensure all tooling is clean and that Calibration tool in tool magazine slot “C”.

9.12.1.5 Select Edit on FC150 manager bar. Then go to Cycles/Manual.

9.12.1.6 Select the appropriate cassette definitions from the drop down menu. Select TestKSF4 for the substrate. Select TestKSF2 for the chip. Note that the TestKSF4 and TestKSF2 cassettes are by default

9.12.1.7 Select the appropriate substrate definition from the drop down menu. Note that the term “substrate definition” in this case refers to the type of bonding recipe. Select TestTC.

9.12.1.8 Set the definitions by selecting the Set Cassette and Set Substrate buttons.

9.12.1.9 Load substrate by selecting the Load function group bullet, then choose Substrate from Cassette to Chuck Phase A and press execute. A dialog box will appear, select OK to load substrate on chuck.

9.12.1.10 Load chip to arm by selecting Chip from Cassette to Arm and executing. The arm should automatically pick up tooling from tool magazine (tooling location predefined in cassette library), and then load the chip from the chip cassette. IMPORTANT: Next select the “check vacuum” option. The value for the tooling vacuum should read < 3000. If this value does not read < 3000, the tooling has not been properly secured to the arm. If the tooling is not properly secured, quit the manual control. The chip/tooling should automatically unload. Clean tooling and attempt reload. DO NOT attempt to continue processing unless the tooling vacuum value is < 3000. Failure to abide to this procedure can result in severe damage to the tooling!!!

9.12.1.11 Select the Chuck Positioning bullet, and then execute the chuck position function (position #1). The system will place the chuck directly under the arm at this point.

9.12.1.12 Select the Alignment bullet and alignment phase H. Execute than press OK to begin the alignment process.

9.12.1.13 Using the joysticks, focus on both the chip and substrate. Note the microscope for the substrate depicts the image with a red hue. The microscope for the chip depicts the image with a green hue. Note that the PgDn and PgUp keys control illumination intensity.

The theta correction sequence is a powerful means to align dies without having to worry about manually correcting for rotational misalignment. In this way the User must only be concerned about misalignment in the x and y directions. Align the substrate to chip using theta correction sequence as follows:
9.12.1.14 The Chip View box will indicate which corner of the chip and substrate the microscope should be viewing currently. Use the joystick to move the microscope to this corner of the dies. Note that the microscope's image will be exactly inverted with respect to the Chip View box notation.

9.12.1.15 Locate the vernier on the chip and center on screen with microscope. Align substrate to the chip vernier by using right joystick (x and y directions) to move the chuck.

9.12.1.16 Check the parallelism of the two dies by pressing F7. Choose NO when asked to run automatic laser leveling. Choose Center, then align the two crosses using the joystick. Finally, press OK to exit parallelism.

9.12.1.17 Refocus and realign the verniers of the chip and substrate if necessary. Press F1 to set the origin (x and y chuck origins should go to zero)

9.12.1.18 Press F8 to enter the theta correction sequence. F8 again to toggle to the opposite corner of the dies. This will be indicated by the Chip view box. Once again, focus if necessary and align verniers moving in x and y direction only. Press F8 again. The software will compute the necessary theta compensation, and rotate the die appropriately. Realign verniers if necessary using x and y directions only. Continue to toggle back and forth with F8 and aligning in this manner until the vernier sets for both chip and substrate are perfectly matched.

9.12.1.19 Press OK to exit the theta alignment sequence. OK again to exit the alignment sequence.

9.12.1.20 Select Bonding cycles function group from the manual operation screen. Select the type of bonding cycle that the substrate definition refers to - e.g. thermo-compression for TestTC.

9.12.1.21 A graph of the bond cycle should appear, and the bonding cycle will run to completion.

9.12.1.22 When the bonding cycle is complete, enter the alignment mode again (Phase H). Focus on the verniers of the two quartz dies. Use F8 to view opposite corner. Record the error in the x and y directions (each short line represents 0.5µ of error, each long line represents 1µ of error. Exit the alignment mode by pressing OK twice.

9.12.1.23 Unload the chip from the chuck by selecting the unload function group and choosing Chip from Chuck to Arm (Chuck does not move) option.

9.12.1.24 Repeat steps 9.12.1.12 through 9.12.1.23 at least three times or until the error looks repeatable.

If the error is greater than 1µ in any direction then perform the following microscope adjustment

9.12.1.25 From a perfect alignment, select F9 to manually unlock the door. A prompt will ask if chuck should be go to rest position, select NO. Gently open door and use J5 and J6 to impose an appropriate offset on the substrate microscope objective. The trick is to misadjust the alignment such that the actual post bond alignment error will be reduced. When finished close door and select OK.
9.12.1.26 Repeat steps 9.12.1.12 through 9.12.1.25 until the error is both repeatable and less than one micron in any direction.

9.12.1.27 Unload the die pair. Select the Unload function group and choose Chip from arm to cassette. Next unload the substrate by selecting Substrate from chuck to cassette.

9.12.1.28 Exit manual mode by selecting Quit. The chuck should return to its rest position and the FC150 is now ready to build parts.

10.0 Qualification Procedure

10.1 Potential new Users should arrange ahead of time to have an existing User review FLIPCHIP operation. Casual questioning (e.g. "Hey, can you review this with me for a moment?") is not to be considered an official review period.

10.2 The first question that should be asked during the review period is whether this chapter and the equipment header file has been read and studied? If not, the trainer should insist that it be reviewed before the meeting.

10.3 The "meeting" between the current and new User should be scheduled for enough time to explain equipment operation, load & unload sequence, alignment test, bonding, and review of system errors etc. (I cannot see this taking less than 60 minutes as subtleties of the FLIPCHIP process are sure to come up for discussion). Equipment time may be recharged to new User's account if necessary.

10.4 The training session described in steps 10.1-10.3 should be undergone by new User at least twice. Two different Users should be selected to perform the training.

10.5 Upon successful completion of step 10.4, new users should take the written FLIPCHIP test. Tests are administered by Nanolab Office staff, and are graded by BSAC Engineering staff (Matt Wasilik). Estimate 2-3 days for grading. Satisfactory completion of this test will enable the new User to meet with a Superuser for qualification.

10.6 Superusers will first ask: "who trained you?" of the new user. "Training" implies adequately following steps 10.1-10.3 above. The Users identified as being the trainers will be responsible for the information conveyed by the new User during the qualification (that is to say, if erroneous information has been relayed).

11.0 Troubleshooting Guidelines

12.0 Figures & Schematics
<table>
<thead>
<tr>
<th>Bonding accuracy (3σ)</th>
<th>Thermo-compression</th>
<th>General Reflow</th>
<th>Localised Reflow</th>
<th>UV-cured Epoxy</th>
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</thead>
<tbody>
<tr>
<td>XY parallelism</td>
<td>± 3 µm</td>
<td></td>
<td>± 1 µm * also in Z</td>
<td>± 3 µm</td>
</tr>
<tr>
<td></td>
<td>± 20 µrad</td>
<td></td>
<td>± 20 µrad</td>
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<td>Substrate set point</td>
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<td>Chip Temp set point</td>
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<td>Force Control</td>
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<td>0.25 Newton</td>
<td>0.3-500 N (1 000 N)</td>
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<tr>
<td>UV Illumination Control</td>
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<td>50-100 mW/cm²</td>
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**Table 1**

*Note: UV cured option not currently available with Nanolab FC150*
### Table 2

<table>
<thead>
<tr>
<th>SiC TOOLING</th>
<th>MAXIMUM ALLOWABLE FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestal Tool #1</td>
<td>50 kg</td>
</tr>
<tr>
<td>Calibration Tool</td>
<td>50 kg</td>
</tr>
<tr>
<td>Micro Pick-up Tool</td>
<td>1 kg</td>
</tr>
<tr>
<td>Pedestal Tool #2</td>
<td>50 kg</td>
</tr>
</tbody>
</table>

*Figure 1*

- bonding arm
- tooling
- chip
- optics
- optics stage
- substrate
- chuck tooling
- stage

*Figure 2*

- Z axis motor
- Universal Bonding Arm
- Granite bridge
- Heated arm
- Die pair
- Heated chuck
- FORCE
- HEAT

*Granite Base*
Be sure to know:

1. Definitions and process terminology used in this document
2. Flipchip process capacities e.g. expected bonding accuracy for a given arm
3. The different basic tool configurations with flipchip
4. All joystick functions during the alignment phase