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FUNDAMENTALS OF FORMATION

CHAPTER 1

FORMATION FLIGHT ORGANIZATION

First, we need to define some of the basic terms we use. Simply put, any group of more than one aircraft is called a "flight." A flight may consist of 2 aircraft, 16 aircraft or 116 aircraft, all flying with respect to one another.

Flights are made up of "elements." An element consists of a flight leader and a wingman. All flights are made up of elements. There are never more than 2 aircraft in an element. For instance, a flight of four aircraft is made up of two elements, a flight of six is made up of three elements, and so on.

If there is an odd number in the flight, then one of the elements will contain only one aircraft. A three-ship flight will normally utilize the concept of a "phantom" #4, acting as if there were a fourth aircraft on the wing of #3.

Let's discuss a flight of four aircraft. The aircraft positions are numbered #1 (flight leader or Lead), #2, #3, and #4. There will be two elements and therefore two element leaders. One element leader is designated as the flight leader (#1), and another lead-capable pilot will normally fly the #3 position and act as deputy lead. The wing pilots will be in the #2 and #4 positions. The two elements will maintain integrity within the 4-ship flight.

Within a 4-ship, #1 will usually be the most experienced pilot of the group. Number 3 (deputy lead) will be the next most experienced, and preferably a lead qualified pilot. The #2 and #4 wing pilots will typically be the junior flight members. ***Never put a non-formation qualified or inexperienced pilot in the lead of a formation.***

Formation Configurations

There are numerous ways to arrange formations, some becoming very elaborate. A formation may fly in different configurations at different times during a flight. The basic formation configurations are fingertip, echelon, and trail. Most other configurations are variations of these.

Fingertip

Fingertip is the standard flight configuration. It is so named because a 4-ship formation resembles the fingertips of your hand when viewed from above. "Fingertip strong left" resembles your left hand; "fingertip strong right," your right hand. In fingertip, the wing pilot maintains a bearing line normally in the 30° to 45° range aft of #1, depending on the aircraft type, with slight vertical spacing down from #1, as well as lateral wingtip spacing.

Formation configuration changes are executed from the fingertip position. If the flight is in a configuration other than fingertip, the flight leader will regroup the flight into fingertip before moving to a new configuration.

Echelon

Echelon is a configuration where all the wing aircraft are either to the right (echelon right) or to the left (echelon left) of #1. The aircraft all maintain the same relative position on the fingertip bearing line, each flying off the preceding aircraft. Echelon is used in the traffic pattern, and to position aircraft for pitchouts. Echelon is limiting in that Lead can only turn away from the flight. We will explain more differences later.

Trail

Trail formations are flown, as the name implies, with the wing pilots following in trail behind #1. There are two distinct types of trail formation—close and extended. We will discuss the differences further in the maneuvers chapter. Extended trail is generally used in situations where greater maneuverability is desired.

CHAPTER 2

MAINTAINING POSITION

Finally, it is time to get to the nuts and bolts of formation. Maintaining position, or “station keeping,” is very challenging. At first, you may wonder why the flight leader can’t seem to keep his aircraft flying straight and level only to discover in the debrief that he was rock-solid the whole time. As you progress, you will learn to judge relative motion from the leader and make small, prompt corrections to stay in position.

Good formation is the result of recognition, anticipation, planning and always striving for the perfect position. When you do achieve perfect position, you are in a state of equilibrium with the lead aircraft where your relative motion to lead is unchanging even while the whole world moves around you in the background.

The key to flying precise, smooth formation can be summarized in two key concepts: recognition and anticipation. Recognition means recognizing slight motion in relation to Lead and making small, prompt corrections as soon as you perceive you are out of position. The easiest way to detect motion is by closely monitoring fixed references on the lead aircraft. Each aircraft type has established references to help you stay in position. By lining up two points on the aircraft you are flying off of, you will be able to detect very small movements. Motion will occur along all three axes. In general, fore and aft spacing is controlled with use of the throttle; vertical position is maintained with the elevator. Lateral spacing is controlled with coordinated use of the ailerons and rudder. Keep your eyes moving; try to avoid becoming fixated on only one reference and, instead, scan all the references as well as Lead’s entire aircraft to detect relative motion and changes in position.

Anticipation means anticipating what the flight leader is going to do next and being prepared to take the appropriate action simultaneously with Lead’s action so as to not fall out of position. For example, if you are practicing a lazy-eight maneuver, you can anticipate as Lead turns away from you, you will have to add power and climb to stay “stacked up” in the proper fingertip position. If you do not anticipate this maneuver and bring the power in late, you will immediately fall out of position.

Here are some pointers and techniques that you may find useful:

- Relax! Just as in basic flying, you must feel what the airplane is telling you. Tension leads to over-controlling, which can cause oscillations that are tough to stop.
- Trim the airplane. Being out of trim increases fatigue.
- Try resting your right arm on your leg to steady your hand, providing a stationary reference.
- Rest your left hand on either the base of the throttle quadrant or adjacent to the prop lever to gauge movement and reduce over-controlling.

This is a simplified way of dividing up the control inputs and corrections. Seldom, though, is it that easy. Most of the time, corrections will have to be combined. For instance, if you are low and apply backpressure to move up into position, you will most likely fall behind unless you add power to maintain your airspeed.

Being behind the fingertip bearing line or aft of station is referred to as being “sucked,” while

being ahead of the line is called “acute.” (Memory aid: Being behind sucks while being ahead can be dangerous—or acute).

When out of position, first correct to the fingertip bearing line. That way, your relative motion to the lead aircraft will always have the same appearance. (The only exception to this is if you are too close to Lead. In this case you should first obtain more lateral spacing, and then correct to the line.) The next most critical error to correct for is vertical position, and finally, lateral spacing. Your instructor will have you practice exercises that help increase your judgment and teach you the corrections required to get you back into position.

When flying in the #4 position, you will fly in reference to #3, your element leader. In fingertip, #3, in turn, maintains position on #1. You will be able to see #1 “through” #3, and this will help you anticipate #3’s movements, but your station keeping will normally be in reference to #3. However, in bumpy air, it may be easier to maintain position by looking through #3 at #1 and reference #1 rather than trying to follow each gyration of #3.

Turns in Fingertip

When Lead rolls into a turn, the maneuver will immediately put you out of position unless you anticipate and make the required control inputs. This occurs because you are transitioning from straight-and-level flight, where you and Lead are flying the same distance, to flying concentric turn circles, where you and Lead are flying different distances. It is like a merry-go-round, where the inside horses are traveling a shorter distance while the outside horses are traveling a longer distance relative to one another. So it will be for you, depending on whether you are on the inside or outside of the turn. You will maintain the same relative position while rolling into and out of bank. This means that besides rolling with Lead, you have to move vertically to stay in position. This change in vertical position, combined with the difference in distances traveled, requires a power change. All this happens while Lead is rolling into the turn, but the corrections must be taken out when Lead stops rolling and is established in the bank. The effects are reversed when rolling out of the bank. We will dissect specific examples.

Turns Into the Wingman

Let’s take the case where you are #2, on Lead’s right side. Lead begins a smooth roll to the right. Match Lead’s right roll to match your bank angle. At the same time, you will need to descend to maintain vertical position. This descent will increase your airspeed, causing you to get ahead of Lead, unless you coordinate with a power reduction. This effect will be compounded by the fact that, on the inside of the turn, you are flying a smaller circle and will therefore travel a shorter distance than Lead. Once Lead stops rolling and is stabilized in the bank, you will have to stop the descent and adjust power to stay in position. These are the individual control inputs explained; now how is it really done? As soon as Lead starts to roll towards you, simultaneously reduce power, roll with Lead and apply forward pressure to stay in position. There, isn’t that easy?

Turns Away from the Wingman

Now let’s look at the case where Lead turns away from you. In fingertip right (2-ship), Lead starts a left turn. You will have to climb and roll to stay in position on the wing. This will require back pressure to move up vertically, and also a sizable power addition lest you lose airspeed and fall behind. Keep in mind, you are also on the outside of the turn flying a larger circle, and thus must increase airspeed slightly to keep with Lead.

Here’s what will probably happen on your first few “turns away.” You will be a little slow to roll, which will push you out away from Lead. Thus, to stay in position vertically will require a larger climb. You will probably not add enough power, which will cause you to get sucked. So, there you are, wide, below and behind Lead, with full throttle and unable to catch up. With time you may catch back up with Lead; generally about the time Lead decides to roll out. To keep this from happening, make positive inputs as soon as Lead rolls. Add a bunch of power, stay right with Lead’s roll, and ease on up to stay in position. If you add too much power initially, it is easy to correct by taking a little off. However, it is difficult to catch back up if you are shy with the power and fall behind.

Once Lead reaches his/her desired bank and stops his/her roll, ease off the backpressure, stabilize your bank, and adjust power to maintain position. Now get ready; anticipate Lead rolling out of the bank. Lead's rolling out of the left turn will have the same effect as rolling into a right turn—it is just a turn *into* the wing pilot.

One final comment: these turning effects will be exaggerated *even further* when flying the #4 position due to your greater distance from Lead.

Echelon Turns (Low Wing Aircraft)

When turning in echelon formation, all turns will be away from the wing pilots. Turning more than a few degrees into the flight could cause a dangerous situation where the wing pilots (especially #4) cannot prevent going ahead of Lead, or could possibly lose sight of Lead.

Echelon turns away from the flight are accomplished differently than in fingertip. As we covered above, in fingertip everyone maintains the same position references and relative position. In echelon turns, the wing pilots maintain the same lateral spacing, however they **do not** move up vertically to stay on the same lateral plane as Lead. Instead, all aircraft will move up just enough to be on the same **horizontal** plane as Lead. This gives the wing pilots a bigger power advantage to stay with Lead. As Lead rolls into the turn, match bank angles and climb only slightly to split the lead aircraft with the horizon line. The references will be demonstrated to you, but the horizon should bisect the longitudinal axis of the preceding aircraft. Since you are on the outside of the turn, you will be traveling a longer distance than Lead. Add power to stay in. Maintain the same lateral spacing from Lead in the turn. When Lead starts to roll out, reduce power as you roll back out with Lead.

There are two times when you would normally fly echelon: first, in 3 or 4-ship formation when all the wingmen are positioned on one side of #1 and second, when you are in the traffic pattern. At other times, Lead may direct you to fly echelon for the sake of practice (in 2-ship, in the practice area, for instance).

Summary

That covers the basics of remaining in position, turns, climbs, and descents. Your first few formation flights should concentrate on building a strong foundation in these basics. Once comfortable with these principles you will move on to bigger and better things.

CHAPTER 3

FORMATION TRAINING MISSION

Now that we have discussed the basics of formation, we can move on to discuss what happens in the course of a typical formation training flight. Below are the basic components. This chapter will address the first four components in detail. Chapter Four will deal specifically with maneuvers, and Chapter Five will explain the last three components of a formation flight.

1. *Briefing*
2. *Engine start and taxi*
3. *Takeoff*
4. *Rejoins after takeoff*
5. *Formation maneuvers*
6. *Landing*
7. *Taxi and shutdown*
8. *Debriefing*

Briefing

The briefing is the single most important part of the flight. It is essential for the flight members to discuss how the flight will be conducted so that everyone knows what to expect and what is expected of them. The flight lead conducts the briefing, ensuring all members understand their role. The flight leader will plan and brief the flight logistics and maneuvers in the sequence

they are to be flown. *Fly the plan as briefed.* Leads will use a briefing checklist. Be prepared to take notes for reference. Prior planning might even allow the flight leader to make up formation profile cards for flight members to refer to in the briefing and during flight.

Safety topics and a discussion of emergency procedures will be included in the briefing. Wingmen who encounter difficulty while in formation, must immediately notify Lead. The nature of the emergency will determine whether the distressed aircraft's pilot will lead or fly on the wing. In some situations (for instance airspeed indicator failure) the pilot would be better off flying on the wing. The radio will be used to sort out the problem unless NORDDO, in which case HEFOE signals will be used. See the *FAST Radio Communication and Visual Signals* guide for all communications protocols.

Engine Start and Taxi

Engine starts will be initiated with visual signals, when possible. When ready to start, the wingmen, beginning with #4, will each pass the "thumbs up" signal up the line to #1. When #1 gets the "thumbs up" from #2, Lead knows all the aircraft are ready. Lead will then give the signal for engine start (index finger pointed skyward, with rotating motion). In an air show environment, where all aircraft are visible to the spectators, Lead may brief to start on an exaggerated "head nod." When Lead's chin hits his chest, press the start button. Complete normal start and after start procedures.

If unable to see one another, engine start will be accomplished at a set time. After sufficient time has passed for all members of the flight to get their engines started and systems checked, #1 will check the flight in on the briefed frequency (i.e., "*Raven, check*"). All flight members will respond, in order ("2, 3, 4"). If not ready, state the time needed (i.e., "*Raven three needs 2 minutes*").

The pilots taxi out, assuming proper positions as they leave the parking area. Using uniform spacing, wingmen will taxi, as briefed, behind the preceding aircraft. Normally two to four ship-lengths is adequate spacing.

Reaching the run-up area, wingmen will try to line up in echelon on the taxiway, or in a position to see #1's visual signals. The flight performs the run-up together on #1's command (same visual signal as for start). When ready for takeoff, pass a "thumbs up" signal up the line to #1.

Takeoff

Takeoff can normally be performed in two-ship elements or single-ship, interval takeoffs. The type of takeoff used will depend on conditions. Formation takeoffs are the most efficient, but may not be possible depending on runway width, crosswinds, gusty winds or other limiting conditions.

For single-ship, interval takeoffs, Lead may decide to assemble the formation on the runway prior to brake release or allow aircraft to roll onto the runway individually and initiate the takeoff without first assembling the flight in position. In either case, do not begin your takeoff roll until the preceding aircraft is airborne or the minimum takeoff interval has been achieved, however briefed. Then proceed with a normal full power takeoff.

Lead will taxi into position allowing enough room for the following element. Lead will normally line up on the downwind side of the runway. This allows the wind to blow Lead's wake away from the wing pilot. If the wind is light, Lead may position himself down sun, or on the convenient side to effect the rejoin after takeoff. The wingman will line up on the opposite side of the runway in the acute position, slightly ahead of the normal fingertip bearing line. The wing pilots should be in the center of their side of the runway with a minimum of 20 feet of wingtip-to-wingtip clearance. (100 feet is the minimum runway width required for training.) This assures that the wingman will quickly clear Lead in the event Lead aborts or experiences directional control problems (as in the case of a blown tire). Use the visual reference demonstrated by your instructor. Elements will space themselves about 100 feet behind the preceding element. Note that the spacing will be much closer for mass formation takeoffs.

When the wing pilot signals he/she is in position with a head nod, Lead will give the run-up signal. Run power up to the briefed power setting and check engine instruments. The wingman will give a head nod signaling ready for takeoff. An exaggerated head nod by Lead will signal

brake release. When Lead releases brakes, he/she will smoothly advance power to the briefed power setting which will provide the wing pilot with a power advantage. As wingman, advance power to stay with Lead. If you start moving ahead of Lead in the early stage of the takeoff, it is better to tap the brakes lightly than reduce power. During takeoff roll, if you have your power way back to stay with Lead, ask Lead to push the power up. Call "*Raven 1, push it up.*" Conversely, if you have trouble keeping up with full power, call "*Raven 1, gimme one.*" Lead will only reduce power once. If proper position cannot be maintained after Lead makes a power reduction, the takeoff should revert to single-ship takeoffs for both aircraft. Lead will never try to manipulate power to move "backwards" to regain element takeoff position.

Lead will accelerate to slightly above normal takeoff speed, then rotate smoothly. The wingman matches Lead's rotation and stacks level (Lead's head on the horizon). Lead will ensure the wingman is safely airborne and at least 50 feet agl, clear of obstacles and stabilized, and then will signal for gear retraction (thumb gesturing up, followed by head nod, or reverse head nod, as briefed). After the gear is retracted, the wingman will move into the normal fingertip position.

Subsequent elements will perform individual formation takeoffs. Wait until the preceding aircraft become airborne, or the minimum takeoff interval has been achieved, before brake release.

Takeoff Abort

In the event of an abort, the aborting pilot will call it out on the radio ("*Raven 3, aborting*"). The non-aborting pilot will apply full power and continue the takeoff. Pilots of following elements will not release brakes. If necessary for safety, Lead may call "*Raven flight abort*" and all aircraft will abort. In this case it is very important to maintain lateral separation. Keep directional control and do not cross over the runway centerline.

Rendezvous After Takeoff

Whether performing single-ship or multiple-element takeoffs, the formation will have to join up once safely airborne. It's important to brief this thoroughly since local conditions and mission requirements will likely dictate the type of join up used. Rendezvous can be done in a turn, straight ahead, or some combination of the two. A turning rendezvous is much faster since the trailing aircraft can use angular cut-off to fly a shorter route to catch Lead. If departing enroute to a destination, it might make more sense to join up while Lead is wings level, on course.

When performing turning rejoins, #2 will always join to the inside of the turn. With a second element, #3 and #4 will always join on the opposite side of #2. If a straight-ahead rejoin is performed, #1 will reduce power to a setting that will give the wingmen a speed advantage. A detailed discussion of how to perform rejoins will be covered completely in the next chapter.

Enroute to the Training Area

Once everybody is onboard, Lead will take the flight to the training area. As much as feasible, once Lead has leveled off in the practice area, he/she will maintain a constant power setting throughout the maneuvering. Wingmen will normally set their RPM at max continuous and use the throttle as necessary to stay in position. Be aware, this will not apply to those aircraft that have critical over-boost and/or under-boost limitations. When clear of the departure airport, Lead may call for a frequency change to the discrete or "tactical" air-to-air frequency to be used in-flight. Also, before starting maneuvers, Lead should give the wingmen a chance to check over their aircraft systems and engine instruments. This may be initiated by calling for a fuel or ops check. Alternately, Lead may send the flight to route formation by signaling with a tail-wag. Once everyone has a chance to complete their checks, Lead will give a wing rock to have everybody move back into close formation and begin maneuvers.

CHAPTER 4 MANEUVERS

Let's go through the maneuvers that make up a typical formation training flight. We will discuss the different formation configurations, changes in formation configurations, and other maneuvers.

Wing-work

One of the first maneuvers you will be practicing falls under the heading of “wing-work.” This maneuvering consists of a series of turns in combination with pitch changes—a lazy eight in formation. Wing-work allows you to practice station keeping throughout a wide variety of attitudes, eventually achieving up to plus or minus 20° of pitch and up to 45° of bank. These are the parameters used in the wingman evaluation ride, but you will likely be able to “hang in there” with up to 60° of bank once you become proficient

Cross-under

The cross-under is used to move flight members from one side of the flight leader to the other. The flight leader may want you to change sides for a variety of reasons: to set up for a pitch out maneuver, to keep you from looking into the sun, to help clear for traffic, or just to give your neck a break. The signal for #2 to cross under is a clenched fist held up vertically. The signal for the second element (#3 & #4) to cross under is the clenched fist “pumped” up and down, twice.

Cross-unders are accomplished in three stages that with proficiency become one fluid movement. The three stages are:

1. Down and back
2. Across
3. Forward and up

First, reduce power slightly to start moving down and straight back. Move to a position below #1 to stay out of the wingtip vortices and prop wash. Once you have nose/tail clearance with #1, add power to hold position. Anticipate the power increase to prevent falling too far behind.

To move across, change your heading only one or two degrees. Roll into a few degrees of bank (less than five), and then roll right out. This will give you the heading change you need to drift smoothly across. Do not stay in a bank, as your heading will continue to diverge from #1. Fly wings level to the other side. Add power as you move across to prevent falling behind #1—you are flying a slightly longer flight path than #1.

When you have wingtip clearance, return to #1’s heading. Add more power to move up and forward into the normal fingertip position.

Most students initially fall behind during cross-unders. Think of the maneuver as having one slight power reduction followed by three big power additions. To fly good cross-unders, you must anticipate each power change and make the smallest possible changes in pitch and bank. Cross-unders may be performed in turns when you are proficient. Use caution to stay clear of wingtip vortices and prop wash. Do not fly directly under #1. Always maintain nose/tail separation.

One final point to remember as you become proficient: The cross-under is not a race to the opposite side, it is a deliberate, controlled and precise repositioning of your aircraft.

Diamond Formation

The diamond formation is a 4-ship configuration often flown for flybys. In the diamond, #4 will fly the slot position below and behind #1.

To send the #4 into the slot, #1 will signal #3, who acknowledges the flight leader, then passes the signal to #4. The signal is four fingers held up, then fist held up with thumb extended, motioning rearward. Number four then performs a modified cross-under into position, calling when in (“*Raven 4 is in*”). To reconfigure back into fingertip, #1 will make a radio call, or use a small wing rock.

Route Position

Route is a variation of fingertip. In route, the flight loosens up a minimum of 2 to 4 ship widths out to a maximum of 500 feet from Lead. It is used to relax on cross-country flights, to give the flight some “breathing room” in high traffic areas, or to accomplish in-flight checks of systems, fuel or other operational tasks. The signal to loosen formation is a quick rudder walk, or tail wag.

Wingmen move out laterally, and are free to maneuver as far forward as line abreast and as far aft as the normal bearing line. To reform the flight, Lead will normally perform a wing rock.

Close Trail

In close trail, the wing aircraft is in the same position as the diamond slot position, directly behind Lead, with approximately one ship-length spacing. The wing aircraft is “welded” to the lead aircraft as it moves, matching bank angles and remaining in position.

To send the wingman to close trail, Lead will motion to the rear, with fist held up and thumb extended. As an alternative signal, Lead may porpoise his/her aircraft gently, using the elevator.

Wingmen should match bank with Lead to remain directly behind. Use power to maintain nose/tail distance. A note of caution: It is more difficult to judge depth perception when looking only at the rear of Lead’s aircraft. If you fall behind and create some overtake in order to move back into position, you may not see excessive closure developing. If you do fall behind, it is better to move slightly to the side to help get a better sight picture and help judge overtake.

Extended Trail

Extended trail is used to teach wingmen the concepts of lead, lag and pure pursuit. Also, since it is the most maneuverable configuration, it may be employed by a flight leader to maneuver around weather, in busy traffic patterns, or other situations where high maneuverability is advantageous. Tactical units commonly use extended trail to stay together while maneuvering aggressively. While we may not be maneuvering as aggressively, the objective is similar: remain within a defined maneuvering area behind #1 using angular cutoff or extension (lead/lag) to maintain proper position. The wingman’s power is fixed to match the flight leader’s power. The wingman maneuvers fluidly within a cone, taking advantage of turning geometry to maintain the briefed nose-to-tail spacing with #1. Extended trail spacing for aircraft with maneuvering speeds below 150 knots is normally 200 feet to 500 feet, while above 150 knots 500 feet to 1500 feet would be used, although different intervals may be briefed. The preferred maneuvering area behind #1 is defined by an inner, 30°-boundary cone measured from #1’s six-o’clock position (known as 30° aspect) to an outer boundary cone of 45° aspect. The wingman will transit the entire cone behind #1 as he maneuvers to maintain relative position in the donut formed by the inner and outer cones.

Angular Cutoff and Extension (2-ship)

Cutoff, also known as “lead,” (just as you would “lead” a clay pigeon when shooting skeet) decreases spacing with #1, and occurs when you select a nose position that will place you on the inside of #1’s turn, either in the horizontal or vertical plane. You will be flying a shorter distance than #1 and will therefore close spacing, if speeds are matched. You can achieve cutoff by selecting an aim point ahead of #1’s nose. Extension, also known as “lag,” increases spacing with #1, and occurs when you select a nose position that will place you on the outside of #1’s turn, either in the horizontal or vertical plane. You can achieve extension by selecting an aim point behind #1’s tail. Pure pursuit occurs when you aim your nose directly at #1. In pure pursuit, you will still close spacing with #1 (assuming your speeds are matched and you are inside #1’s turn circle), but at a much slower rate than you would if you were using the lead technique.

Wingmen should expect the in-trail gap to close when #1 climbs and to extend when #1 descends. This spacing change is due to the change in #1’s speed as #1 increases or decreases pitch. Since this is a dynamic, fluid exercise, you will be continuously alternating between lead, lag and pure pursuit to maintain your desired position, relative to #1. Initially, using cutoff/extension to maintain position will be challenging. It requires practice to develop the judgment necessary to determine aspect, range and closure. If you find you are closing too rapidly, do not hesitate to reduce power or turn aggressively away from #1. Break out of the formation if necessary.

When maneuvering within the cone, be cognizant of #1’s wake turbulence and prop wash. In a turn, #1’s wake and wash will trail up behind his/her flight path. Wake turbulence can be quite strong, especially close behind #1, and while pulling Gs. Also, it is quite possible to lose sight if directly behind and maneuvering above #1’s flight path. Since losing sight of #1 is not acceptable, the wingman should move laterally relative to the lead aircraft to prevent #1 from disappearing

under the nose.

A flight is sent to extended trail with a radio call and can be accomplished several different ways. With the flight in close trail, Lead can enter a shallow turn while the wingmen continue straight ahead until each sees the appropriate spacing and then turns to establish position. With the flight in echelon, Lead can break away in a pitch-out maneuver with each wingman breaking in rapid succession to achieve proper position. Each aircraft will call when in position. The lead aircraft will then perform a series of modified lazy eight maneuvers, keeping positive Gs on the aircraft. This gives the wing pilots an opportunity to practice using angular cutoff and extension (lead, lag and pure pursuit).

When exiting extended trail, a good Lead technique is to roll into and maintain a level, 45° bank turn until all the wing pilots have stabilized behind Lead. Lead will then roll wings level and reform the flight with either a radio call or a wing-rock.

Angular Cutoff and Extension (4-ship)

The same extended trail techniques apply when flying with more than two aircraft except that each aircraft in the formation will fly in reference to the aircraft ahead. Number 3 will maneuver relative to a cone emanating from #2 and #4 will likewise maneuver relative to #3.

Rendezvous

The rendezvous is used to join up aircraft into fingertip formation as safely and expeditiously as possible. The rendezvous is an exercise in geometry and energy management. For a turning rendezvous, the goal is for #2 to be joined up within 180° of turn. Unless otherwise briefed, or directed by Lead over the radio, all wingmen will rejoin in numerical order. Pitchouts are used to provide spacing for rejoin practice. They are also used in the traffic pattern to take spacing for single-ship, interval landings.

Pitchout

For flights of more than two aircraft, the flight leader must configure the flight in echelon prior to signaling for a pitchout. The signal is the same as for run-up and start (point skyward, with rotating motion). He/she will then hold up the number of fingers to indicate the break interval in seconds (normally 3 to 4 seconds). Number two will acknowledge the signal, but does not pass it on. Each succeeding aircraft will match #2's interval using their own count. Lead then clears carefully in the direction of the turn and breaks away using up to 60° bank, with a level turn of approximately 180°. As soon as Lead breaks away, the wing pilot must clear ahead, then in the direction of turn. Wait the specified interval and then make a matching turn, clearing carefully for traffic. Approaching the rollout, vary your bank and backpressure to fall directly behind Lead with Lead on the horizon. This is an excellent opportunity to make a quick scan of the instruments and your fuel to ensure all is well. Each pilot calls in position when level and stabilized behind the preceding aircraft ("*Raven 2 in*").

Turning Rejoins

Lead will initiate the rejoin with a wing-rock. Lead will then establish a level turn, using approximately 30° of bank. If rejoin airspeed has not been briefed, or if Lead is not within 10 knots of the briefed rejoin airspeed, Lead will make a radio call announcing the airspeed. Lead will hold that speed throughout the rejoin. Once the rejoin has been initiated, wing pilots can expedite the rejoin by accelerating and holding up to 10 knots of additional airspeed.

When Lead gives the rejoin signal (radio call or wing-rock), #2 will start a turn in the same direction as Lead. Number 3 and #4 should delay their turn so as to avoid becoming acute.

The rejoin can be thought of as a four-part process, although the four parts are occurring, more or less, simultaneously.

Part 1

Adjust your altitude to place Lead's aircraft just above the horizon line. This positioning should occur after the pitchout, as soon as you roll out in Lead's six-o'clock position, and then carried through the remainder of the rendezvous. It is important to maintain this nearly co-altitude

position—the rendezvous is a level-flight maneuver, not a climbing maneuver (an exception to this will occur when executing a rendezvous after takeoff, during climbout).

Part 2

Use lead/lag to achieve a moderate aspect angle (approximately 45°).

Part 3

Crosscheck your airspeed. Remember, you can carry up to 10 knots above the briefed rejoin airspeed to help expedite your rejoin. Tip: Airspeed controls closure rate.

Part 4

Approximate Lead's bank angle and fuselage alignment. This is accomplished by orienting your aircraft so as to place Lead on your canopy or window in about the same place that you would normally view him/her if you were in fingertip formation, except lower, since you are in a turn (Lead will be very close to the canopy rail or the bottom of your window).

Monitor your vertical position and modulate your bank angle to maintain proper aspect. If Lead's vertical tail moves forward of the wingtip, you are falling behind the rejoin line—pull lead to correct as being behind the rejoin line delays the rejoin. If the vertical tail is moving aft of the wingtip you are ahead of the line and need to pull lag to correct. Tip: Bank controls bearing line (aspect). Being ahead of the rejoin line (acute) can create a hazardous situation where you may not have room for a safe under run.

As you close to about 500 feet, monitor your aspect and closure carefully to ensure your movement is controllable. As you close on Lead, shift your sight picture to utilize the normal sightline references for the bearing line.

Turning Rejoins to #2 Position

Unless otherwise briefed, as #2, you will always join to the inside of the turn. Once you close to about 100 to 200 feet, start picking up your fingertip sightline references. As you approach 2 to 4 ship widths out, ensure your closure is stabilized before sliding into the fingertip position.

Under Run

If you appear to have too much closure on Lead, reduce power. If, despite the reduced power, closure is excessive, you will have to execute an under run: keep Lead in sight, roll wings level and pass below and behind Lead (if you are joining from below or high relative to Lead, you will also have to push forward on the stick/yoke). Move to the outside of the turn while maintaining safe nose/tail clearance. The greater your closure rate, the wider you must go to prevent moving forward of Lead. Once outside the turn, do not go higher than Lead (no higher than echelon turn references). After dissipating most of your excess energy, make a controlled return to the inside of the turn with safe clearance and complete the rendezvous (note: some organizations require that the wingman request permission to rejoin the flight after an under run). That controlled return to the inside of the turn will require you to use some of the excess energy to effect a proper rendezvous.

During training you will practice the under run procedure to gain judgment. Your instructor will have you carry extra airspeed and cutoff during the rejoin to make the overshoot realistic. The trick is to retain enough energy after the overshoot to move back to the inside of the turn without getting sucked. Use caution, though, not to pass directly beneath Lead when moving to the inside. If you have too much energy when moving down and to the inside of the turn, another under run may be necessary.

If your rejoin stagnates prior to getting tucked in position, move back to the inside of Lead's turn, advance power as necessary, achieve proper aspect and move into position.

Rendezvous to #3 and #4 Position

The basic rendezvous techniques are similar to the procedure used by #2; however, you have the additional responsibility of monitoring the preceding aircraft. You will also have to carry extra energy in order to make the transition to the outside of the turn. In this respect, the rejoin to the #3 and #4 position is more like an intentional under run. Number 3 and #4 must not rejoin until #2 is under control and is assured of being capable of stabilizing in proper position. Remember, we join "by the numbers," meaning we join in the order of our number in the flight. Move in no closer than 100 feet of the preceding aircraft until that pilot has stabilized in position. If #2 is slow to rejoin, #3 and #4 may have to reduce airspeed and/or cutoff to maintain proper spacing, or even temporarily move to a trail position.

Closing to within approximately 100 to 200 feet, #3 will pick an aim point in space ahead of and to the outside of Lead. The trick is to fly to this aim point while passing behind Lead with nose-to-tail clearance. Number 3 has to fly to this aim point because by the time the sweep to the outside is executed, Lead and #2 will have moved forward in space. Proper execution will place #3 precisely in fingertip position on the outside. Avoid abrupt control pressures and rapid throttle movements in consideration of #4.

Number 4 should plan to pass below and behind the lead element and #3 with safe nose/tail clearance, using the same technique as #3, and then slide into fingertip. If #3 is slow to rejoin, #4 should not join on #3 before #3 has completed his/her rejoin on the flight. It is important that #3 have plenty of space to maneuver should a situation develop that requires an under run. If #4 is overtaking #3, #4 should reduce airspeed and/or cutoff to maintain spacing. As with all rejoins, if in doubt, the six o'clock position is usually the safest position until all preceding aircraft get stabilized. After all preceding aircraft have stabilized, move to the inside of the turn to reestablish cutoff, capture the correct aspect angle, and effect a proper rejoin.

Element Rendezvous

There will be situations, such as after formation element takeoffs, where #3 and #4 will rejoin as an element. In this case, Lead and #2 have made a formation, element takeoff and the deputy lead (#3) and #4 have also followed with their own element takeoff. To rejoin the flight, the deputy lead will perform a normal rendezvous to the opposite side as #2, which should, under normal circumstances, be the outside of the turn. If, as a result of the initial runway positioning, #4 will be between the Deputy Lead and the flight, the deputy lead must cross #4 to the inside of the turn. In other words, deputy lead will never "push" #4 up into the flight during the rejoin. As deputy lead crosses behind and below the flight to move up and to the outside, #3 fingertip position, #4 will transition below and behind deputy lead to move up and to the outside, #4 fingertip position.

Straight Ahead Rendezvous

Lead will make a radio call or rock his/her wings to initiate a straight-ahead rendezvous. Lead then reduces power to give wingmen an airspeed advantage. Lead will brief or callout the rejoin airspeed so that wingmen can monitor their overtake. As #2, rejoin to the side you vacated, unless directed otherwise. The second element will take the opposite side. Straight-ahead rejoins for #3 and #4 are the same as for #2. Initially, the wing pilots will use power as necessary to gain an airspeed advantage. From here, start a bid to achieve proper aspect angle and monitor your overtake. Fly the rejoin offset to the side you will rejoin to and plan to arrive in the route position with slightly more speed than Lead. After ensuring your closure is stabilized, use the extra energy (speed) to slide into fingertip.

If your closure rate is excessive during a straight ahead rejoin, reduce power to slow your advance. If you are going to overshoot, turn slightly away from Lead. "S" turning and/or slipping may help to reduce your overtake, but make sure you keep Lead in sight. Resume the rejoin when Lead begins to stop moving back in your canopy. If you overshoot to the point that you cannot keep Lead in sight, break out of the formation. Clear and turn positively away from the flight.

Caution: When overshooting straight ahead, there is a tendency to move the stick in the direction you are looking; that is towards Lead. This may cause your aircraft to close toward or pass in front of Lead creating an unsafe situation.

In-Flight Position Changes

Before each flight you will be briefed on the position you will fly. Maintain the position assigned for the duration of the flight unless Lead directs a position change. Position changes will normally be made with the formation in level flight, in fingertip, using hand signals. Lead changes are typically predetermined in the pre-flight briefing and then executed as planned. Lead will point to the pilot he/she wants to assume the #1 position and then point forward. The pilot accepting the #1 position will acknowledge the lead change by nodding, tapping the top of their head and then pointing forward. The new Lead will then add power and move forward to take the #1 slot. As the new Lead moves into position, the other aircraft will take up fingertip position on him/her.

In a 4-ship fingertip flight, the lead will normally be passed to the deputy lead (#3). The lead can be passed to #2, but cannot be passed to #4 without first reconfiguring the flight.

Another useful technique is to reconfigure the flight into echelon. From the echelon position, the lead can be passed to any of the flight members, including #4. The key, as always, is a thorough pre-flight briefing so that all pilots know how the lead change will be accomplished and what their new position will be in the reconfigured flight.

Following the lead change, the new Lead should check the flight in to assure that everyone understands their new flight position.

Separating a Flight Into Elements

When you are flying in a formation of three or more aircraft, there may be a point where the formation has to be split up into individual elements. This will occur if Lead wants to make element landings or in the situation where one flight member has an in-flight problem and needs to return for landing.

No matter how many aircraft are in the flight to be separated, the objective is the same: you want to achieve lateral and/or vertical spacing. There are a number of ways to achieve this and the method will normally be covered in the pre-flight briefing.

Here is one technique: at Lead's direction, the deputy lead (#3) will start a climbing or descending turn away from the formation while Lead and #2 maintain straight and level flight. This will produce safe, expeditious separation for the flight.

CHAPTER 5

TRAFFIC PATTERNS

Try to remain aware of your position while Lead brings the flight into the traffic pattern. This helps you anticipate Lead's actions. Lead will direct the flight to change to the appropriate frequencies on arrival. Landings are performed either single-ship or in elements.

Single-Ship, Interval Landing

Single-ship, interval landings may be necessary on a narrow runway, in strong crosswinds, or in other situations. If traffic, or bird activity, is a factor, Lead may decide to put the flight into route or trail for safety. As there are several ways a flight can take spacing in the pattern, this is normally pre-briefed. We will cover a couple of the methods.

The 360° Overhead Pattern and Break

The 360° overhead pattern is an efficient way to get a formation flight on the ground. For those not familiar with an overhead pattern, it involves flying an upwind leg aligned with the landing runway at pattern altitude (called "initial"), followed by a steep-bank "break" turn to the downwind when over the runway, and a close in, descending turn to base and final approach. This pattern allows the you to bleed off airspeed in the turn to downwind for gear extension, and keeps the aircraft in close to the runway.

In a formation overhead pattern, the flight will take spacing in the break to downwind. Lead will configure the flight into echelon for the traffic pattern in preparation for the overhead break. On initial, Lead will give the pitchout signal followed by the desired break interval. Lead will break

over the numbers if possible. Each pilot then takes their interval and breaks so as to roll out on downwind behind the preceding aircraft, at the briefed airspeed. The spacing achieved in the break from initial to downwind will not always be the desired interval for landing. Maintain the pre-briefed downwind airspeed and create the desired landing interval by adjusting your turn from downwind to final.

Lead will extend landing gear and/or flaps when abeam the numbers on downwind and start a descending turn to touchdown. This position, normally abeam the numbers on downwind, at pattern altitude, where Lead begins the descending turn to final, is known as “the perch.” The perch position can shift upwind or downwind, depending on wind conditions, traffic congestion or other mitigating factors. Each pilot will reduce power in the break and lower the gear after rolling wings level on downwind. Lead normally flies a tight pattern; lowering flaps, turning base (at the perch), and making a continuous descending turn to a short final. Wing pilots also extend their flaps at the perch and fly their pattern based on the interval established by #2 but in no case will they land with less than the minimum safe interval prescribed by ops specs. Do not become so distracted that you fail to complete your before landing checklist!

For staggered landings, Lead lands slightly long on the downwind side of the runway and normally rolls out to the end. Each wingman lands on alternating sides of the runway and then taxis to Lead’s exit point. Do not cross in front of a succeeding aircraft until cleared to do so by that aircraft. For example, if #4 was on landing rollout, under control with adequate spacing and at a safe speed, he/she could call “*Raven three’s clear to cross,*” and #3 would know it is safe to cross in front of #4.

For “hot/cold” side landings, Lead will land slightly long, normally on the side of the runway that corresponds to the runway turn off (cold side). Each wingman will land on the opposite side from Lead (hot side) and, once slowed to a reasonable taxi speed, cross over to the cold side.

Downwind Break

If a 360° overhead is not feasible, another way to take spacing is on the turn to base leg. This is also known as the “downwind break.” Lead will slow the flight to the briefed pattern speed by downwind. If the downwind break was not pre-briefed, Lead will call for the flight to take spacing on the turn to base.

Lead begins the base turn as appropriate. After the interval, each wingman will turn his/her respective base. As each pilot starts the base turn he/she will reduce power, lower the gear, extend the flaps and complete the before landing checklist. Land on alternating sides of the runway or use hot/cold procedures, as briefed.

Element Landing

For multiple-element formations, the flight leader will break the flight into single elements for element landings. Each element Lead will slow the aircraft by downwind to configure. The flight leader will signal for gear extension with the thumb extended down from a closed fist, and gesture downward. Actual extension occurs with Lead’s exaggerated head nod: lower the handle when Lead’s chin hits his/her chest.

Flap extension will be signaled with a “biting” motion of the thumb and fingers. Again, extend your flaps on Lead’s head nod.

The wingman stays in fingertip until turning final. On final, Lead aligns with the downwind side of the runway. When the wing pilot begins to see the runway in his/her peripheral vision, he/she then moves up to stack level with Lead (Lead’s head on the horizon). The wingman will use the same acute position utilized for formation takeoffs. When the wingman begins to acquire the runway with peripheral vision he/she will also start to divide attention between Lead and the runway. The wing pilot will plan to land in the center of his/her half of the runway with no less than 20 feet of wingtip clearance.

In the flare, Lead will make a smooth, slow power reduction to just above idle power. The wingman will continue to fly off Lead during the flare and landing, monitoring the runway. The

wingman should touch down slightly before, or at the same time, as Lead. If the wingman touches down after Lead, it is likely that he/she will “float” past Lead on the runway. After touchdown, maintain relative position on your side of the runway and begin normal braking. If the element Lead must cross the runway centerline to exit, the wingman must ensure that he/she has safe spacing, safe speed and is under control before making the call “*Blue Lead is clear.*”

Element Go-Around

If a go-around is required, Lead will announce his intentions on the radio (“*Raven flight of two going around*”), smoothly advance power to a setting that is appropriate for the go-around yet still allows a safe margin for the wingman and either call, or signal, for flap and gear retraction, as appropriate. The wingman, upon hearing the go-around call, will anticipate the maneuver, add power, and take appropriate measures to maintain a normal element takeoff position, reconfiguring the aircraft as directed by Lead.

Taxi In and Shutdown

Once clear of the runway, the flight leader will assemble the flight for taxi to the ramp. Flaps will be retracted on Lead’s signal or as briefed. Visually confirm you have the correct handle!

If parking together, the flight should shut down together. If conditions permit (i.e. no aircraft, people, or obstructions behind the formation), Lead will signal to perform the pre-shutdown run-up. On Lead’s signal run power up to the briefed power setting. Reduce to idle on Lead’s signal (hand held up, palm open, motioning rearward). Lead then gives a slashing sign across the throat, and an exaggerated head nod. Shut your engine down when Lead’s chin hits his chest.

Debrief

After everyone has a chance to secure his/her aircraft, and perhaps get a cold beverage, the flight members will assemble for the debrief. The goal of the debrief is to improve safety, performance, communication, and understanding.

Lead (or the Check Pilot) will direct the debrief. The debrief should be instructional with emphasis placed on the “what, why and how”—what happened, why it happened and how to improve performance. All aspects of the flight are critiqued. Following the flight leader’s analysis, he/she will solicit inputs from the individual flight members. Lead cannot possibly observe every single aspect of the entire flight so it is important to hear everyone’s perspective. Make sure all questions are answered and uncertainties are resolved. Although a formation flight will seldom go as well as hoped, learning can always take place.