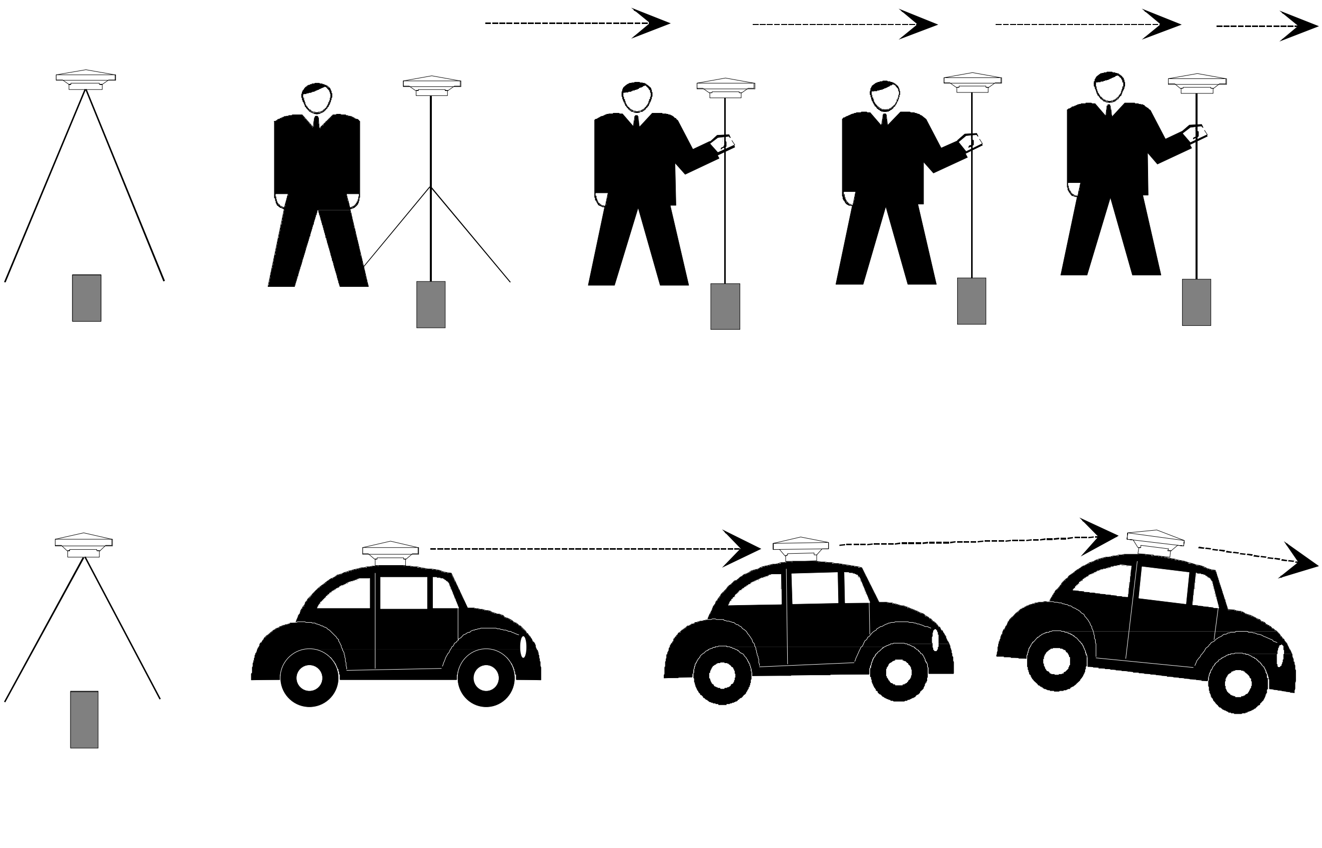
GPS - System 300

Guidelines to Stop and Go and Kinematic GPS Surveying

Controller V 3.30 and higher

SKI V 2.1 and higher



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Contents

1. Introduction

GPS surveying has become extremely popular due to the advantages of accuracy, speed, versatility and economy. Further advances in the areas of speed and economy have been made with the introduction of Stop and Go and KinematicGPS surveying.

This booklet outlines how to carry out Stop and Go, True Kinematic and Kinematic on the Fly surveys and emphasizes those points to which particular care has to be paid.

Although this booklet has been written specifically for Leica GPS - System 300, much of the information is of a general nature and applicable to all dynamicGPS surveying.

It is advisable to study the booklet "Guidelines to Static and Rapid Static GPS Surveying" before reading this booklet. Much of the information in "Guidelines to Static and Rapid Static GPS Surveying" applies equally well to Stop and Go and TrueKinematic.

2. Stop and Go, True Kinematic and Kinematic on the Fly surveying

This booklet concentrates on high-accuracy dynamic measurements using carrier-phase observations. System 300 supports 3 different dynamic methods: Stop and Go, TrueKinematic, andKinematic on the Fly.

Provided that the ambiguities are resolved in the initialization part of the chain and lock to the satellites is maintained while moving, positional accuracies of about 1 to 3 cm + 1 ppm root mean square and accuracies in height of about 2 to 4 cm + 1 ppm root mean square can be achieved.

3. Basic Principles of GPS Surveying Using Dynamic Methods

3.1 Basic Principles of Stop and Go and True Kinematic Surveying

Stop and Go and True Kinematic GPS measurements are similar. Both comprise:

❶ An initialization part, which is needed in order to be able to resolve the initial ambiguities in the SKI post-processing software.

❷ A moving part in which the ambiguities are carried forward in the SKI software.

The only difference is that in the moving part of Stop and Go fixes are related to actual points, whereas in the moving part of True Kinematic fixes are related to instants of time.

The initialization part plus the associated moving part is termed a chain: A Stop and Go chain or a Kinematic chain.

The initialization part is important. It has to be successful. The ambiguities have to be resolved (i.e. fixed to integer values) in the SKI post-processing software. Only then can the ambiguities be carried forward by SKI in the moving part of the chain.

The initialization part can be carried out by using either:

❶ A Rapid Static fix
or
❷ The occupation of a known point

During the moving part of the chain, at least 4 satellites have to be tracked. If the number of satellites drops below 4, due to loss of lock or a setting satellite, SKI will not be able to carry forward the ambiguities and the chain has to be terminated.

The GDOP should not exceed 8 if results to the accuracy levels discussed in section 2 above are to be achieved. GDOP values of 5 or lower are preferable.

3.2 Basic Principles of Kinematic on the Fly (KOF)

Kinematic on the Fly measurements provide the trajectory of a moving sensor without the necessity of a static initialization. The sensor can be moved from the first observation epoch onwards. Accurate results, based on phase measurements, require the use of the dual-frequency receiver SR399/SR399E.

A KOF chain consists of a moving part only.

The same accuracy as for True Kinematic observations can be achieved, provided the following requirements are met:

✔ A minimum of 5 satellites are tracked from the first epoch onwards
✔ Good geometry (low GDOP values)
✔ No cycle slips or losses of lock during the first 200 seconds of a chain
✔ A maximum distance of about 5 km between reference and rover is maintained.

The ambiguities will be carried forward within a chain as long as a minimum of 4 satellites without cycle slips are available. As soon as this number drops to less than 4 satellites, another 200 seconds of cycle-slip free data to a minimum of 5 satellites are necessary to again obtain high-accuracy results.

SKI will postprocess KOF data provided the "Ambiguity Resolution on the Fly"- option (AROF) is installed and will provide results in a similar way as for TrueKinematic chains.

The processing is carried out automatically in 2 steps: In a first run the ambiguities are fixed by default, the attempt to resolve them starts after the first 200 seconds of data, the resolved ambiguities are then transferred forward as long as a minimum of 4 satellites are tracked without cycle slips. In a second iteration the resolved ambiguities are backsubstituted to the beginning of the chain, thus high-accuracy coordinates are obtained from the first epoch onwards.

The KOF method is recommended when a static initialization is not feasible or possible, for instance in a hydrographic survey where the antenna is installed on the mast of a survey vessel and cannot be kept steady for several minutes.

3.3 Time-Tagged Points within a KIS and KOF chain

Within the moving part of a KIS chain or a KOF chain, discrete points can be captured with a few keystrokes on the Controller.

Time-tagged points can be related to either the instant of time when a certain function key was pressed (instantaneous points) or to the next (following) recorded observation epoch.

Time-tagged points can be associated with point identifiers and attributes in a similar way to Stop and Go points.

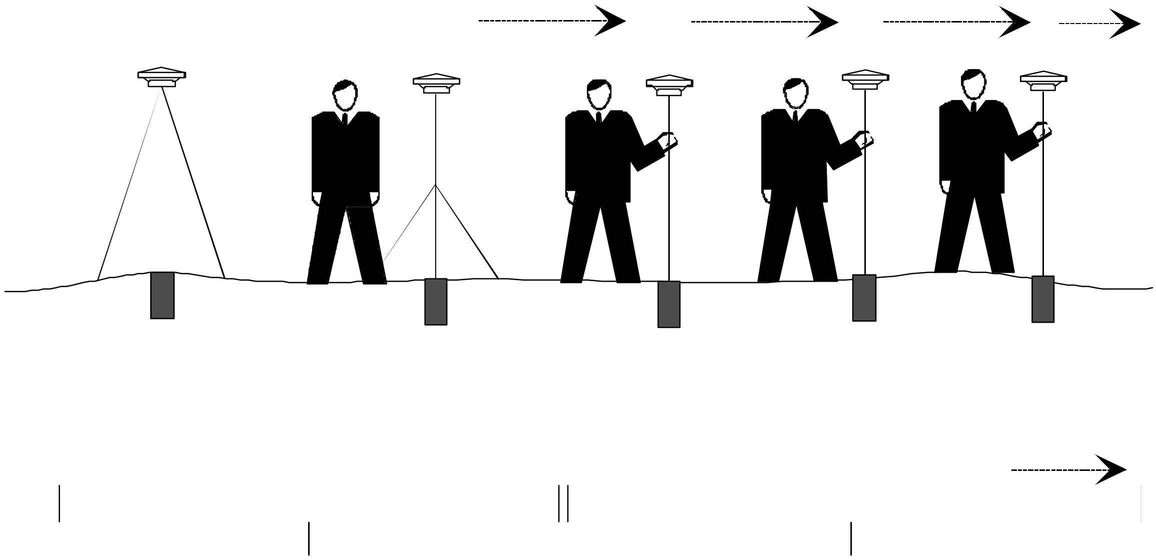
The results of such observations are both the trajectory of the moving antenna and the discrete points captured during the survey within the moving part of the chain.

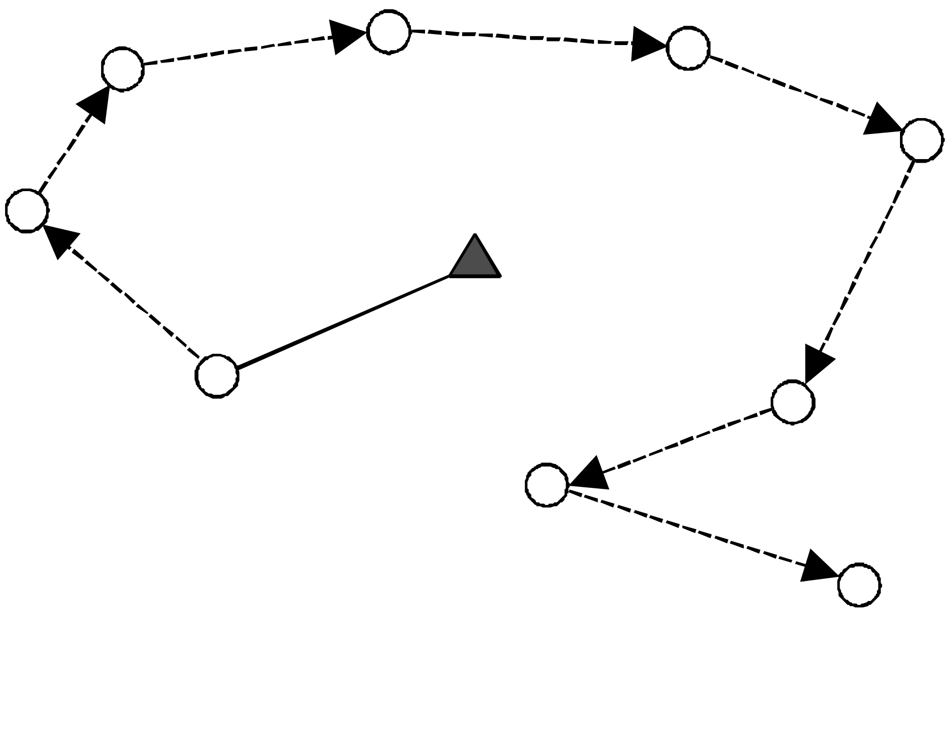
Instantaneous:
Instantaneously-recorded points are obtained by interpolation between the results of the previous and following epoch. This is the recommended method when the antenna is moving and accuracy is of less importance, for instance when the roving antenna is mounted on top of a car and certain details along the road have to be captured without actually occupying these points.

Next epoch:
A much more accurate way is to relate time-tagged points to the next (following) epoch and to occupy such points until the next observation is recorded at the point. This leads to an accuracy similar to that achieved with Stop and Go.

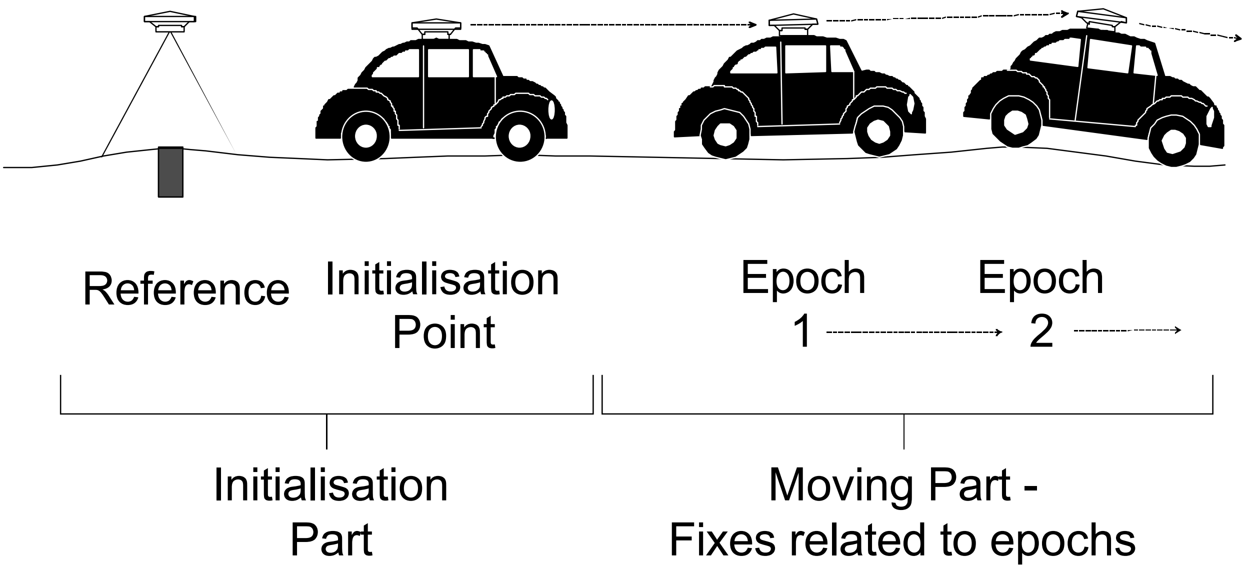
Thus the results of a KIS/KOF chain with time-tagged points can be considered to be a combination of a kinematic trajectory and discrete points as in Stop and Go.

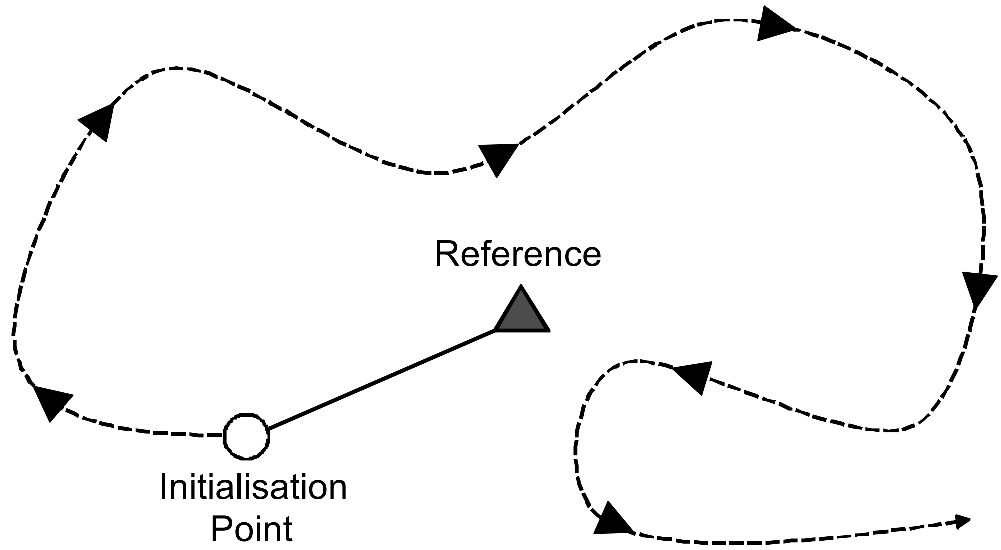
STOP and GO (SGS)



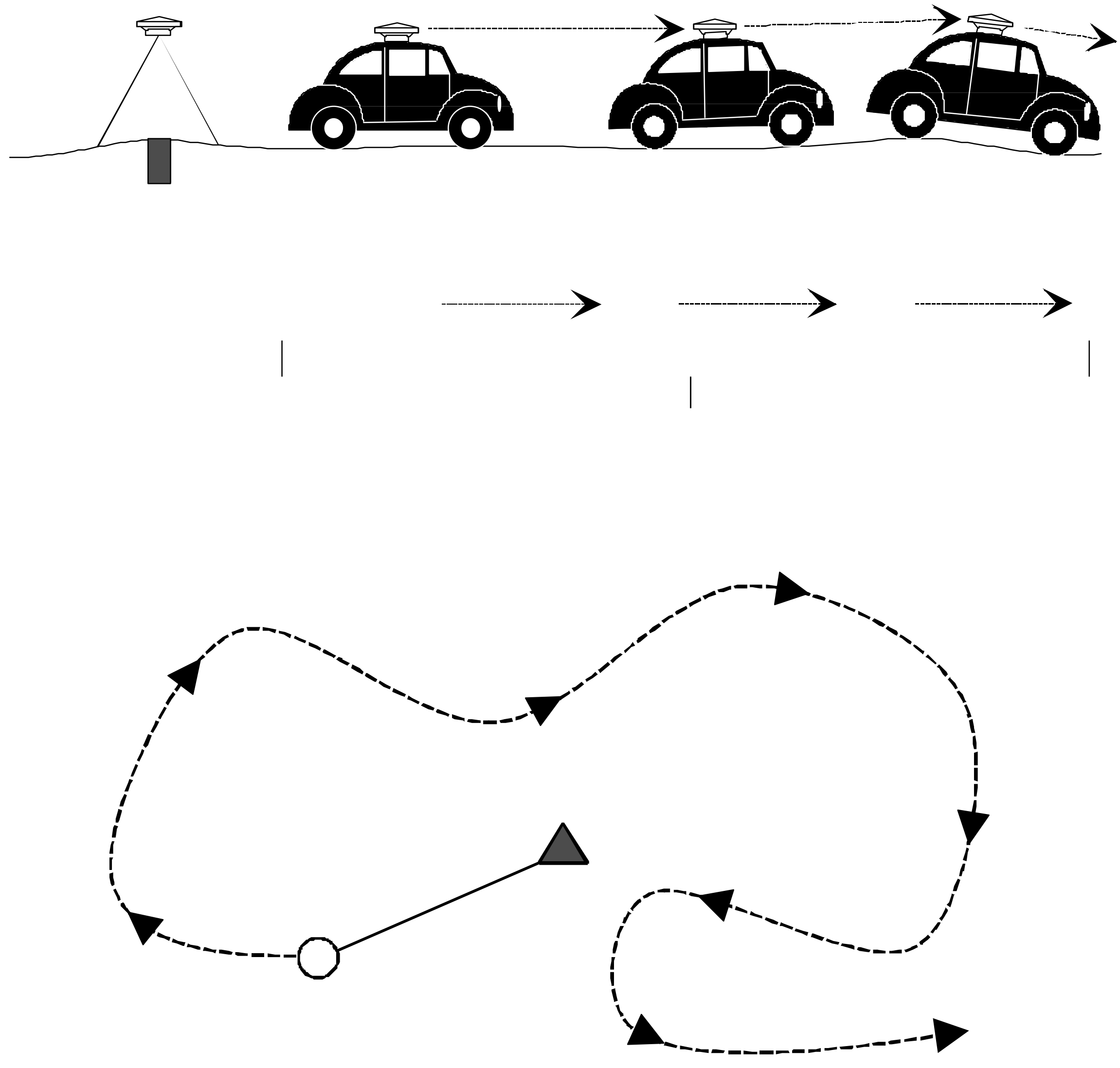


TRUE KINEMATIC (KIS)

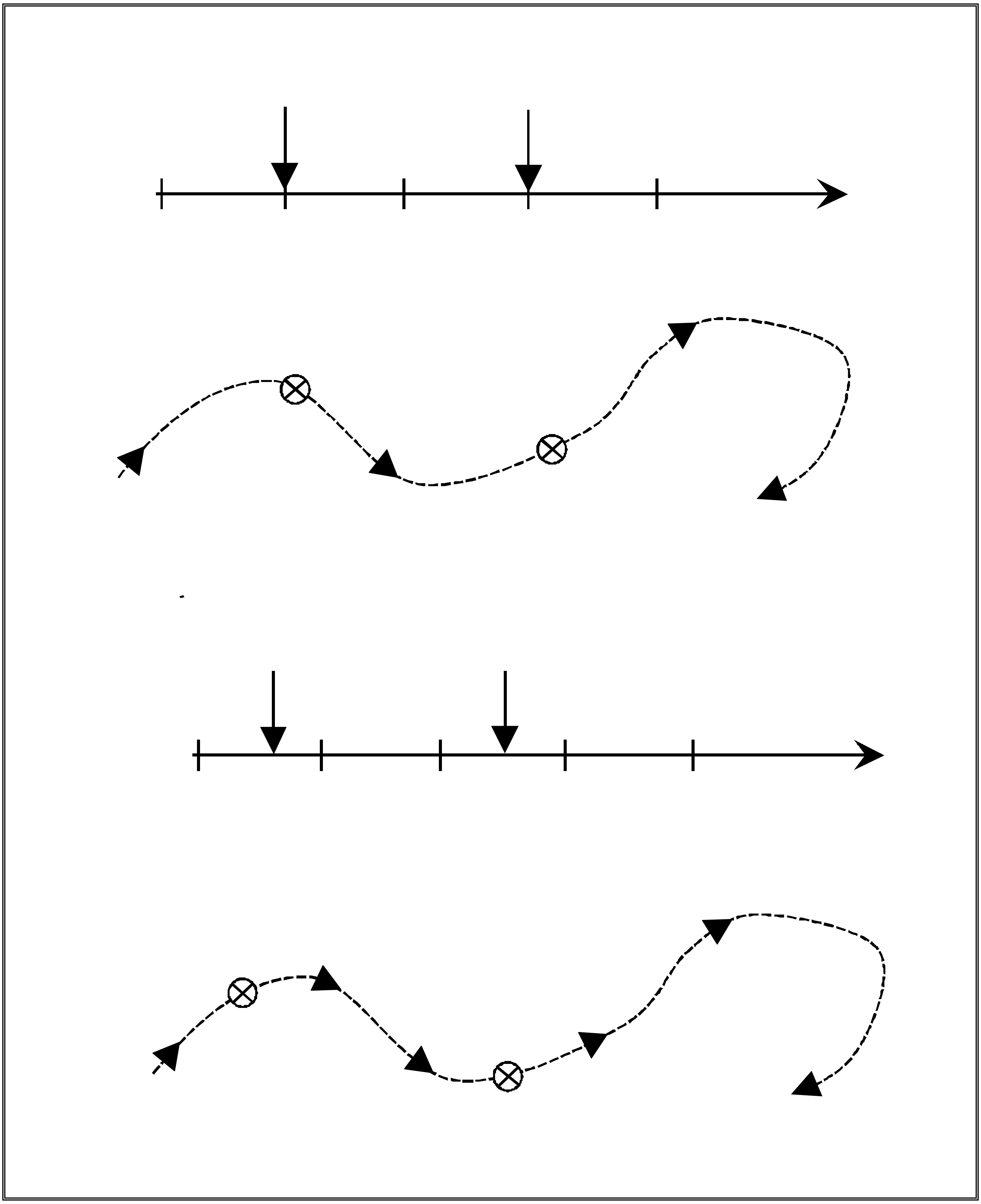




KINEMATIC ON THE FLY (KOF)



TIME-TAGGED POINTS



4. Satellite availability for SGS, KIS and KOF

For successful Stop and Go, True Kinematic and Kinematic on the Fly measurements, it is essential to work in a window with a strong satellite constellation.
Choose a window with as many satellites as possible; the more satellites there are the more you can afford a loss of lock to a satellite! Try to choose windows with satellites at reasonably high elevations; high-elevation satellites are less likely to be obstructed and thus suffer loss of lock!

For Stop and Go, and Kinematic

Window	**Satellites, Elevation, GDOP**
Good Window	*5 or more satellites, satellites above 20°, GDOP ≤ 5*
Can be used but not recommended	*4 satellites, satellites above 15°, GDOP ≤ 8*
Should not be used	*4 satellites, GDOP > 8*
Cannot be used	*3 satellites or less*

For Kinematic on the Fly

Window	**Satellites, Elevation, GDOP**
Essential for first 200-300 secs for initialisation of chain	*5 or more satellites, if possible above 20°, GDOP ≤ 5*
Can be used after first 200-300 secs initialisation	*4 satellites, satellites above 15°, GDOP ≤ 8*
Should not be used	*4 satellites, GDOP > 8*
Cannot be used	*3 satellites or less*

5. Reference Station

The reference station is critical. A loss of lock at the reference receiver has exactly the same effect as a loss of lock at the rover. The reference receiver has to operate reliably and be safe from interference.

Sites for reference receivers should be chosen for their suitability for GPS observations.

✓ No obstructions above 15° elevation.

✓ No reflecting surfaces that could cause multipath.

✓ Safely away from traffic, passers-by, and interference.

✓ No powerful transmitters (radio, TV, communication links etc.) in the area.

✓ Reliable power supply:

Consider using two batteries
Or a car battery
Or, when possible, a transformer connected to the mains.

✓ Ample data-logging capacity:

Consider using 2 MB memory card
Or optional 1 MB internal memory of Controller
Or a PC with SPCS software
Or a PC with Multistation software

The reference receiver does not have to be set up on a known control point. It is far better to set up the reference receiver at a site that fulfills the requirements listed above than at a known control point that is not really suitable for GPS observations.

Set up the reference receiver at a suitable site and fix its position with Static or Rapid Static measurements from known points.

6. Need for one known point in WGS 84

The computation of a baseline in data processing requires that the coordinates of one point (reference) are held fixed. The coordinates of the other point (rover) are computed relative to the fixed point.

In order that the SKI post-processing software can resolve the correct ambiguities, the coordinates for the "fixed" point (reference) of the baseline have to be known to within at least 20 meters in the WGS 84 coordinate system. Whenever possible, the WGS 84 coordinates for the fixed point should be known to within 10 meters.

This means that for any precise GPS survey the coordinates of ONE site in the network have to be known in WGS 84 to about 10 meters. The coordinates of all other points, including the reference stations for Stop and Go and TrueKinematic surveys, can then be computed.

There are three possibilities for obtaining reliable WGS 84 coordinates for one site:

1. WGS 84 coordinates may be available.

2. WGS 84 coordinates can be derived from local coordinates using published approximate transformation parameters and the Datum and Map component of SKI.

3. WGS 84 coordinates can be computed using the Single Point Position computation in SKI.

Remember that Selective Availability (SA) degrades the Single Point Position. The only way to average out the effects of SA and thus obtain a result to the required accuracy is to compute the Single Point Position for a point for which several hours of observations are available. The longer the observation period the better will be the Single Point Position.

The need for reliable WGS 84 coordinates for the fixed (reference) point of the baseline applies to all GPS surveying: Static, Rapid Static, Stop and Go, TrueKinematic and Kinematic on the Fly.

7. Baseline lengths and position of the reference receiver

Land-surveying applications

Stop and Go (SGS) and True Kinematic (KIS) measurements should be the preferred methods in land-surveying applications. SGS and KIS rely on a static initialization and are therefore generally somewhat more reliable and robust thanKinematic on the Fly (KOF).

Each Stop and Go and True Kinematic chain starts with an initialization part. This will often be a Rapid Static fix. The shorter the baseline the less time you need to observe for the Rapid Static fix.

In Stop and Go and True Kinematic surveys you have to stop and restart if the number of satellites tracked drops to 3 or less due to an obstruction. A new initialization is needed. This means either stopping for sufficient time for a new Rapid Static fix, or returning to occupy a previously fixed (known) point. The shorter the baseline to the reference station, the shorter the time you have to observe for the Rapid Static fix.

Thus, for routine land-surveying applications, it is well worthwhile trying to keep baseline lengths as short as possible by setting up the reference receiver in or close to the working area.

For production purposes in standard land-surveying applications, the practical limit for high-accuracy Stop and Go and True Kinematic is probably about 5 - 8 km.

Special applications

As far as the moving part of the chain is concerned, there is, in theory, little restriction to the distance between the reference and the roving receiver. Once the ambiguities have been resolved in the initialization part of the chain, the ambiguities will be carried forward in the moving part provided that the receivers continue to track sufficient satellites with good GDOP and provided there are no critical losses of lock.

Thus, for special applications outside conventional land surveying, it is possible for the rover to move considerable distances from the reference receiver. One has to be aware, however, that as the phase-measurement noise is much higher at long distances, SKI will almost certainly not be able to compute the ambiguities in case of a new satellite rise. Another restriction is that in case of a critical loss of lock, a new initialization using a Rapid Static fix will be impossible at long distances.

Kinematic on the Fly

If Kinematic on the Fly is used in a survey (for instance in hydrographic surveying), the operator should be aware that fixing the ambiguities is more difficult than in a static scenario. To allow for a reliable ambiguity resolution, the distance between reference and rover should be kept as short as possible, with as many satellites above 20° elevation as possible and with a GDOP as low as possible.

In practice, KOF should be restricted to distances of up to about 5 km.

REFERENCE RECEIVER

✓ Critical for all methods:For Stop and Go,Kinematic, andKinematic on the Fly

✓ Choose a good site:

No obstructions
No reflecting surfaces
Safe from interference
No transmitters in immediate vicinity

✓ Position it in or close to working area:

For short baselines
For short Rapid Static observations

✓ Must operate absolutely reliably:

Reliable power supply
Ample data-logging capacity

✓ Need WGS84 coordinates to 10m:

Fix reference receiver from a known point
using Static or Rapid Static

8. The Initialization Part of a SGS, KIS, or KOF Chain

Stop and Go and True Kinematic chains require a static initialization. This can be carried out by using either:

A Rapid Static fix
or
The occupation of a known point

A static initialization is not required for a KOF chain.

8.1 Initializing a SGS or KIS chain with a Rapid Static Fix

When using dual frequency receivers (SR299 or SR299E), a Rapid Static fix is probably the most common way of initializing a chain. The advantage is that the roving receiver can be set up anywhere. It does not have to be on a specific point.

The booklet "Guidelines to Static and Rapid Static GPS Surveying" explains the requirements for a successful Rapid Static fix.

Always observe for sufficient time. Remember that the Rapid Static fix has to be successful for the ambiguities to be resolved in SKI software and carried forward through the moving part of the chain.

Refer to the Stop and Go Indicator in the Controller.

The following table also provides an approximate guide to baseline lengths and observation times for Rapid Static with the SR299. It is valid for mid latitudes under the current levels of ionospheric activity.

No. sats. GDOP ≤ 8	Baseline Length	Approximate observation time	
		By day	By night
4 or more	Up to 5 km	5 to 10 mins	5 mins
4 or more	5 to 10 km	10 to 20 mins	5 to 10 mins
5 or more	10 to 15 km	Over 20 mins	5 to 20 mins

The advantages of short baselines are obvious. The shorter the baseline the less time you have to observe for the Rapid Static fix.

Observations for a Rapid Static fix with single-frequency Sensors should be much longer than with dual frequency equipment. 15 minutes should be the absolute minimum time for Rapid Static with single frequency receivers!

Please refer to the booklets "Notes on using the Wild SR261 GPS Sensor and SKI-L1 Software" for more information on Rapid Static with the SR261 GPS Sensor and "Notes on using the SR9400" for further information about using the SR9400 GPS Sensor.

8.1.1. Rover must be kept steady during Rapid Static fix

The roving receiver has to be kept perfectly steady during a Rapid Static fix. For example:

- On a tripod.
- On a pole in the quickstand.
- On a pole held firmly against a solid object (e.g. a wall).
- On a stationary vehicle.

Any movement of the roving receiver during a Rapid Static fix is interpreted by SKI as phase-measurement noise and may lead to the ambiguities not being resolved.

8.2 Initializing a SGS or KIS chain by occupying a known point

Instead of using a Rapid Static fix, it is possible to initialize a chain by setting up the roving receiver on a known point and observing for at least 4 epochs.

Since a Rapid Static fix takes a relatively long time with single frequency receivers, an initialization on a known point is usually the preferred method when using such equipment.

The SKI software will resolve the ambiguities with the help of the known coordinates and will carry the ambiguities forward through the moving part of the chain.

It is important to understand what is meant by a known point:

- The WGS84 coordinates have to be known relative to those of the reference receiver to the accuracy of the survey, let us say to about 2cm to 3cm.

- These coordinates have to be stored in the SKI data base under the correct point number.

In practice, this will usually mean that the "known" point used for the initialization of a chain has been fixed in one of the following ways:

- Directly from the reference point,
- Or from another point related directly to the reference point,
- Or from a point in another chain based on the same reference point.

In any case, the known point has to be in the same network as the reference point, i.e. the WGS84 coordinates have to be correctly related to each other.

8.2.1. Hold the pole steady when initializing on a known point

Hold the pole steady on the known point, centre the bubble, and observe for at least 4 epochs.

This is all that is required.

8.3 Starting (initializing) a Kinematic on the Fly chain

A static initialization is not required to start a KOF chain. The roving receiver can simply move. The initialization is carried out in SKI using the observations from the moving roving receiver.

Note, however, that the moving antenna has to be kept away from obstructions, which could cause losses of lock, during the first 200-300 seconds of the KOF chain. During these initial 200-300 seconds, a minimum of 5 satellites with good GDOP and elevations as high as possible have to be observed, and no cycle slips have to occur. As long as these requirements are met, the roving GPS antenna can be moved without any problem.

After this initial 200 to 300 seconds period, which is required for SKI to resolve the ambiguities, a KOF survey is identical to a KIS survey.

9. Moving part of a chain (SGS / KIS / KOF)

Provided that 4 or more common satellites are tracked continuously by the reference and the rover, the SKI software should be able to carry the ambiguities, which have been resolved in the initialization part, through the moving part of the chain.

If the number of satellites drops to 3 or less, SKI will no longer compute and carry forward the ambiguities. In this case a SGS and KIS chain has to be closed and a new chain has to be started.

In the case of a KOF chain, another 200-300 seconds of cycle-slip-free data to a minimum of 5 satellites is required to reinitialize the chain and to achieve centimetre accuracy again. Note that the rover can continue to move.

It is important to watch for loss-of-lock messages and to watch the satellite status [X of Y] and the GDOP in the Controller. In addition to watching the [X of Y] status in the main panel, the "Satellite Status" panel can be inspected to check the tracking behaviour on both the L1 and L2 frequencies.

Note that a loss-of-lock message can be due to either:

A temporary loss of lock to a satellite,e.g. due to an obstruction
or
A setting satellite.

10. Watching the Controller in SGS, KIS, KOF: an example

Rapid Static fix, reference and rover

Status Comment

5 of 5 Tracking all 5 visible satellites (at reference and rover). SKI will resolve the ambiguities (fix to integer values) provided that sufficient observations are taken.

Moving part, roving receiver

Status Comment

5 of 5 Tracking all 5 visible satellites. The resolved ambiguities for all 5 satellites will be carried forward in SKI.

6 of 6 New satellite rises. The ambiguities to the new satellite will be computed in SKI. The ambiguities for all 6 satellites will be carried forward.

5 of 5 Loss-of-lock message due to setting satellite. Now 5 of 5. Ambiguities for 5 satellites will be carried forward in SKI.

4 of 5 Loss-of-lock message. Tracking only 4 out of 5 visible satellites. Temporary loss-of-lock to one satellite, but still good geometry with low GDOP. SKI will carry forward the ambiguities for the 4 tracked satellites.

5 of 5 "Lost" satellite tracked again. SKI will re-establish the ambiguities for this satellite. Ambiguities for all 5 satellites will be carried forward in SKI.

4 of 4 Loss-of-lock message due to setting satellite. Now 4 of 4. Ambiguities for 4 satellites will be carried forward in SKI.

3 of 4 Loss-of-lock message: "Warning: <4 sats! reinitialize!" Only 3 satellites tracked. SKI will not compute and carry forward the ambiguities. Close the SGS or KIS chain.

11. Stop and Go

11.1 Mission Parameters

Although you can use a mission such as STSDEF Static Survey Default STS and simply change the parameters, you will probably find it more convenient to define two special missions for Stop and Go: Stop and Go Reference, and Stop and Go Rover.

The reference receiver must be set to STATIC (STS), the rover to STOP and GO (SGS).

Both receivers should be set to record COMPACTED data.

The observation recording rate has to be the same at both receivers.

When choosing the recording rate, consider the data-recording capacity at the reference and how long you want to stay on a point with the rover. A recording rate of 3, 4 or 5 seconds is usually a reasonable compromise.

Example of Mission Parameters for Stop and Go

Parameters	*Reference*	*Rover*
Health / L2 mode	*AUTO*	*AUTO*
Minimum elevation	*15°*	*15°*
Operation type	*STATIC*	*STOP and GO*
Compacted/Sampled	*COMPACTED*	*COMPACTED*
Obs rec-rate static	*5 secs*	*5 secs*

11.2 Stop and Go chain

Initializing with a Rapid Static fix

Remember that the rover must be kept perfectly steady.
Press MEAS (F1)
Enter point id, height reading, antenna offset, (and code if required)
Take sufficient observations (refer to Stop and Go indicator)
Then STOP (F1) the measurement
And press REC-PT (F1) to record the site information
But do <u>not</u> exit mission

Initializing by occupying a known point

The procedure is as for a Rapid Static fix except that a minimum of 4 epochs of observations will suffice. Note that 6 or more is preferable.

Keep pole steady and centered on point
Press MEAS (F1)
Observe for 4 or more epochs, and enter point id. etc.
Press STOP (F1) and REC-PT (F1)
But do <u>not</u> exit the mission

Moving part

Move to the first point of the moving part of chain

Place pole on point, centre bubble, and hold pole steady
Press MEAS (F1)
Check /edit point id., height reading, antenna offset, (attribute)
Wait for at least 4 epochs
Then STOP (F1) the measurement
And press REC-PT to record

Move to the next point, place pole on point etc.
Press MEAS (F1)
Check /edit point id., height reading, antenna offset, (code)
Wait for atleast 4 epochs
Then STOP the measurement
And press REC-PT to record

Remember that it is important to hold the pole steady when on a point.

Watch carefully for loss-of lock messages and watch the satellite status panel. If a loss-of-lock message occurs you can continue to move with the roving receiver provided that the receiver is still tracking 4 or more satellites with a low GDOP.

If the number of satellites drops to 3 or less a warning appears:

"Warning: < 4sats !! reinitialize !!"

You must close the Stop and Go chain either by starting a new chain or by exiting the mission.

If only 4 satellites are tracked and the GDOP is poor (i.e. > 8), it is also advisable to close the chain. Start a new chain as soon as a better satellite constellation with good GDOP is available.

Starting a new chain

If the loss of satellites was due to an obstruction, pass the obstruction and start a new chain by pressing NEWCHN.

You can now start the new chain by initializing with a new Rapid Static fix.

An alternative is to return to a known point and to start the new chain by initializing on a known point. The known point could be one of the last points of the previous chain. Remember to enter the correct point number in the Controller.

Exiting the mission

To exit from Stop and Go, simply press EXIT-M (Exit Mission).

12. True Kinematic

In this booklet the term True Kinematic refers to kinematic measurements based on carrier-phase observations. The ambiguities resolved in the initialization part are carried forward through the moving part of the chain.

12.1 Mission Parameters

Although you can use a mission such as STSDEF Static Survey Default STS and simply change the parameters, you will probably find it more convenient to define two special missions for kinematic: Kinematic Reference, andKinematic Rover.

The reference receiver must be set to STATIC (STS), the rover to KINEMATIC (KIS).

The observation recording rate has to be the same at both receivers. When choosing the recording rate, consider both the data-recording capacity and the recording rate you require while moving. A high recording rate such as 1 second is common for kinematic but calls for a considerable amount of data-recording capacity.

Particularly for the reference receiver, you may find it preferable to use a 2 or 4MB memory card, or a Controller with 1MB internal memory, or even a PC with SPCS orMultistation software.

Set the two receivers to COMPACTED. It is always advisable to use COMPACTED provided the vehicle is moving at normal speeds (up to about 100 km per hour) without excessive acceleration.

Example of Mission Parameters for True Kinematic

Parameters	*Reference*	*Rover*
Health / L2 mode	*AUTO*	*AUTO*
Minimum elevation	*15°*	*15°*
Operation type	*STATIC*	*KINEMATIC*
Compacted/Sampled	*COMPACTED*	*COMPACTED*
Obs rec-rate static	*1 sec*	*1 sec*
Obs rec-rate moving	*-*	*1 sec*
Time-tagged points	*-*	*NEXT EPOCH*

12.2 True Kinematic chain

Initializing with a Rapid Static fix

Remember that the rover must be kept perfectly steady.
Press MEAS (F1)
Enter point id, height reading, antenna offset, (and code if required)
Take sufficient observations (refer to Stop and Go indicator)
Then STOP (F1) the measurement
And press REC-PT (F1) to record the site information

Point id now shows "Ready for move"
Do not exit mission
Press MEAS (F1) to start the moving part of chain

Initializing by occupying a known point

The procedure is exactly the same as for a Rapid Static fix except that it is advisable to observe for at least 4 epochs. Observing for 6 epochs or more is preferable.

Keep pole steady and centered on point
MEAS (F1)
Enter point id, height reading, antenna offset, (code)
Observe for 4 or more epochs
STOP (F1) and REC-PT (F1)
But do not exit the mission

Press MEAS (F1) to start the moving part of chain

Moving part

The rover/vehicle can now move. Recordings will be made automatically at the obs rec-rate moving interval set in the mission parameters, e.g. 1 second.

While moving, watch for loss-of lock messages and watch the satellite status panel. If a loss-of-lock message occurs, you can continue to move with the roving receiver provided that the receiver is still tracking 4 or more satellites with a low GDOP.

If the number of satellites drops to 3 or less a warning appears:

"Warning: < 4 sats !! reinitialize !!"

You must close the Kinematic chain.

Closing the chain

Press STOP (F1). Check height, antenna offset etc. Then REC-PT (F1).
This closes the moving part and therefore the entire Kinematic chain.
(Note that it is not necessary to EXIT-Mission).

Starting a new chain

If the loss of satellites was due to an obstruction, pass the obstruction and start a new chain by initializing with a new Rapid Static fix:

Press MEAS (F1) for new Rapid Static fix of new chain (keep rover steady)
Observe for sufficient time
Press STOP (F1) to stop the measurement
And REC-PT (F1) to record
This ends the Rapid Static fix
Then press MEAS (F1) to start the moving part of the new chain
All observations will be in the new chain.

An alternative is to return to a known point and to start the new chain by initializing on a known point. The known point could be one of the last points of the previous chain. Remember to enter the correct point number in the Controller.

Exiting the mission

To exit from theKinematic mission, simply press EXIT-M (F2).

12.3 Time-tagged points - Next Epoch

Detail points along the trajectory of a roving antenna can be surveyed using the so called "time-tagged point" feature. Time-tagged points can be captured in the moving part of a KIS chain or in a KOF chain.

Example:
Detail points have to be surveyed within a kinematic chain to about centimeter accuracy. In this case, the Mission parameter for "time-tagged points" should be set to "NEXT EPOCH".

The initialization of the chain is as explained above.

Once the roving unit is taking data during the moving part of the chain, the function key "REC-TM" (F-2) becomes active in the main panel. Upon pressing it, the key changes to "REC-PT". Before pressing REC-PT, the correct point identifier, antenna height and antenna offset should be keyed in. Codes can also be stored in the usual way. Once all the point-related information has been entered, "REC-PT" has to be pressed.

The GPS antenna has to be held steady on the point until the next epoch after pressing "REC-TM" is recorded in the Controller .

During post processing, SKI will compute the coordinates for the epoch. All the recorded point-related information will be attached. It can be seen that KIS (or KOF) with time-tagged points referring to the "next epoch" is equivalent to Stop & Go with one epoch per point.

For successful results with the "next-epoch" time-tagged point function, you must:

Occupy point, keep pole steady
Touch REC-TM (F-2)
Enter Point id, height reading, antenna offset, (codes)

Press REC-PT (F2)
Wait for next epoch to be recorded, or appropriate message
Move on

13. Kinematic on the Fly (KOF)

Kinematic on the Fly refers to dynamic measurements based on carrier-phase observations. SKI will resolve the carrier-phase ambiguities and apply them to every epoch of the chain, thus providing high accuracy coordinates for the entire measurement chain.

Whereas Stop and Go and True Kinematic can be carried out with both single-frequency and dual-frequency receivers, Kinematic on the Fly based on phase observations will only work with dual frequency receivers.

13.1 Mission Parameters

Although you can use a mission such as STSDEF Static Survey Default STS and simply change the parameters, you will probably find it more convenient to define two special missions for Kinematic on the Fly: KOF Reference and KOF Rover.

The reference receiver must be set to STATIC, the rover to KINEMATIC ON THE FLY.

The observation recording rate has to be the same at both receivers.

The same considerations regarding memory capacity apply for Kinematic on the Fly as for True Kinematic.

Set the two receivers to COMPACTED. It is always advisable to use COMPACTED provided the vehicle is moving at normal speeds (up to about 100 km per hour) without excessive acceleration.

Example of Mission Parameters forKinematic on the Fly

Parameters	*Reference*	*Rover*
Health / L2 mode	*AUTO*	*AUTO*
Minimum elevation	*15°*	*15°*
Operation type	*STATIC*	*KOF*
Compacted/Sampled	*COMPACTED*	*COMPACTED*
Obs rec-rate static	*1 sec*	*-*
Obs rec-rate moving	*-*	*1 sec*
Time-tagged points	*-*	*INSTANTANEOUS*

13.2 Kinematic on the Fly chain

A KOF chain consists of one or more sub-chains. A sub-chain is defined as the period for which an ambiguity set for a minimum of 4 satellites is valid. After a complete loss of lock all ambiguities have to be determined again, thus SKI will automatically create a new sub-chain.

A minimum of 5 satellites with low GDOP is required for a successful initialization of all ambiguities at the start of a chain or sub-chain. It is important that the field operator should understand this.

SKI usually requires 200 - 300 seconds of data at a high recording rate (1 to 3 seconds) for fixing the ambiguities (initializing the chain or sub chain). Please note that during this phase SKI cannot fix any cycle slips. If a cycle slip occurs during this phase, all data up to the epoch of the cycle slip will be rejected. Thus another 200 - 300 seconds of uninterrupted satellite data will be necessary for the initialization and to obtain high accuracy.

Starting a KOF chain

Make sure that you start the KOF chain with the rover in an open area in order that cycle slips or losses of lock can be avoided.

A minimum of 5 satellites have to be tracked, the GDOP should be 5 or lower, the elevation to the tracked satellites should be above 20° if possible, and the distance between reference and rover should be as short as possible.

The rover can move. It does not have to be kept steady.

Press MEAS (F1)
Watch the satellite status panel
Carry out the survey, follow a planned route, etc.
Before stopping the chain, enter point id, height reading, antenna offset
Then STOP (F1) the measurement
And press REC-PT (F1) to record the information

STOP / REC-PT closes the chain automatically. Pressing MEAS again starts a new chain automatically.

Keep the chains as short as possible, for instance start a new chain for each new profile.

13.3 Time-tagged points - Instantaneous

If discrete points along a trajectory have to be captured, "time-tagged points" can be stored within a KOF or KIS chain.

Example:

Discrete points have to be captured within a KOF chain while the receiver is moving. In this case, the Mission parameter for time-tagged points should be set toINSTANTANEOUS.

Pressing the REC-TM (F2) key will then cause a time stamp to an accuracy of 0.1 seconds to be recorded.

In post processing, SKI will compute the coordinates of the antenna position for that instant of time by interpolating between the coordinates of the previous and subsequent epochs. All the recorded point-related information (point identifier, height, antenna offset, attributes) will be attached.

The accuracy of the interpolation and therefore of the coordinates will be related to the speed and uniformity of movement of the antenna.

For successful results with the “instantaneous” time-tagged point function, you must:

Start a KOF chain as described above
MEAS (F1) has to be pressed to start the recording during the chain

Press REC-TM (F-2) to capture the time stamp
Enter Point id, antenna height, antenna offset (and attributes)
Press REC-PT (F-2) to store the information

The NEXT EPOCH option (section 12.3.) provides a higher accuracy for time-tagged points than the INSTANTANEOUS option.

Exiting a KOF mission

To exit from Kinematic on the Fly, simply press the EXIT-M key after finishing a chain.

Roving Receiver

Initialization part of a SGS or KIS chain

With a Rapid Static fix
Or by occupying a known point

Moving part of chain

✓ At least 4 satellites have to be tracked
✓ Watch for loss of lock and GDOP
✓ Watch the satellite status [X of Y]
✓ Avoid obstructions if possible
✓ Stop if the number of satellites drops to 3 or less

In Stop and Go

✓ Stay for about 4 epochs on each point
✓ Hold the pole steady on the point
✓ Move only after pressing STOP

Split the work into short chains

✓ If possible, avoid very long chains with many points
✓ Try to use shorter chains
✓ Strike a balance between speed and minimizing risk

14. Data Processing with SKI

14.1 Data-Processing Parameters

In the vast majority of cases, the default settings for data-processing may be accepted and may never be altered by the operator. In some rare cases the following parameter may need to be amended.

Occasionally in the Dataprocessing parameters/More panel the “Cycle slip detection” setting may have to be set to Loss of lock flag only.

14.2 Data processing of SGS and KIS chains

Note that when computing Stop and Go and True Kinematic chains in SKI, you must select the appropriate method of initialization. When selecting the reference and rover stations you will need to assign Stop and Go and Kinematic chains that have initialisation on a known point as such by selecting the Init known point selection tool in the station selection window.

14.3 Data processing of KOF chains

Phase-data processing of Kinematic on the Fly data is only possible with dual-frequency observations and with the AROF (Ambiguity Resolution on the Fly) - option installed in SKI.

From the user's point of view, processing of KOF data runs fully automatically after selecting the reference and the KOF chain(s). Internally the computation is carried out in several different steps.

- First of all a chain may be split into several subchains. A new subchain is automatically created after a complete loss of lock. Within each subchain one set of ambiguities exists and is solved for.
- For a successful ambiguity resolution, about 200 to 300 seconds of cycle-slip free data are required initially, i.e. after the start of a new subchain.
- After that the ambiguities will usually be resolved successfully and the ambiguities can then be carried forward until the end of the subchain. Cycle slips to individual satellites will be fixed provided a minimum of 4 satellites with valid ambiguities are still available.

- In a further iteration, the already-known ambiguities are backsubstituted and applied to the initial observation epochs. Thus highly-accurate results with resolved carrier-phase ambiguities are computed for all epochs of thesubchain.
- The entire computation of the chain, i.e. for all subchains, is carried out automatically in one run.

KOF data should be taken with a high recording rate, e.g. 1 or 2 seconds. Thus after 200 seconds, 100 or 200 epochs of data will be available.

The principle of chains and subchains, and forward and backward processing, can be easily described with a short example:

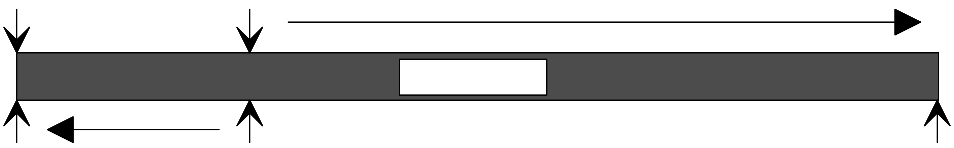
The roving antenna is mounted on a vehicle. After starting data logging at a recording rate of 1 second to a minimum of 5 satellites the vehicle is moved for 500 seconds without cycle slips. After 500 seconds the vehicle passes under a bridge, causing a complete loss of lock, but continues moving for another 500 seconds until data logging is stopped.

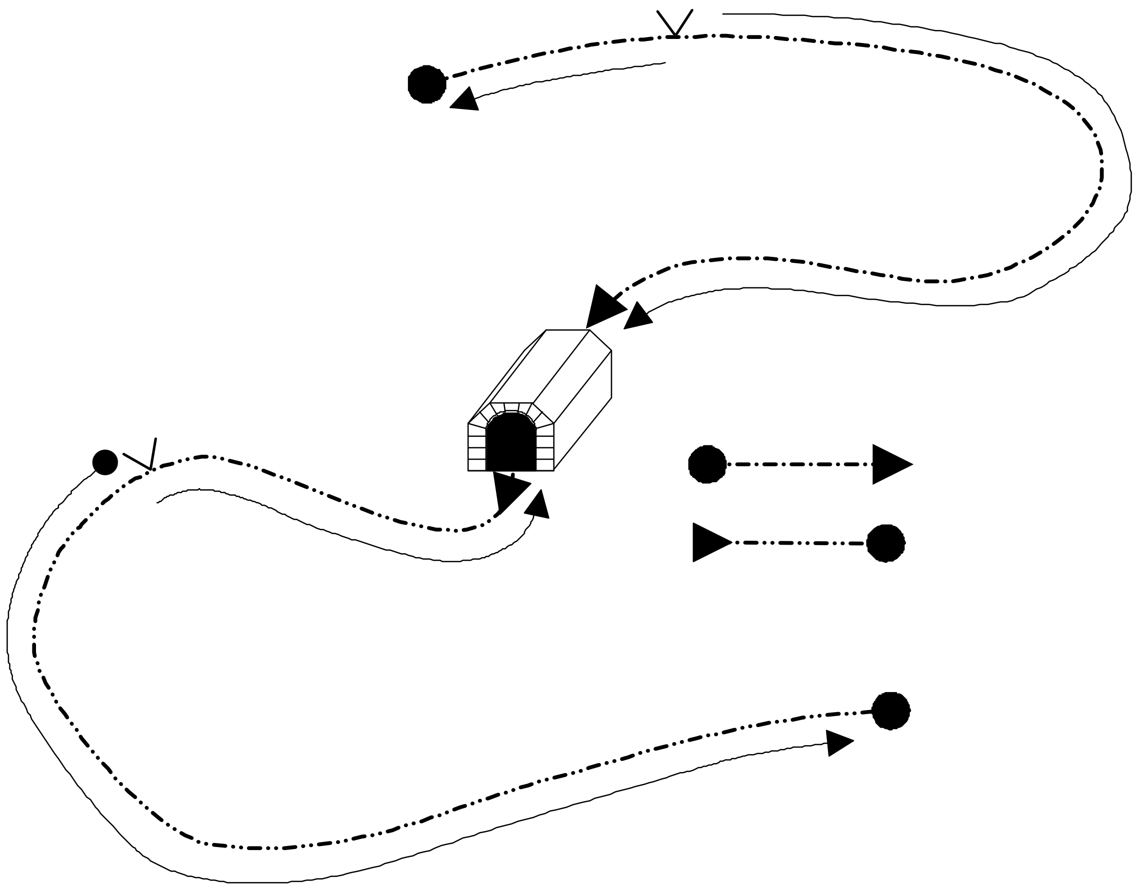
SKI will split this one chain automatically into 2 subchains: from epoch 1 to epoch 500 and from epoch 501 to 1000.

- In each subchain the ambiguities can be resolved after 200 seconds (i.e. at epoch 200 and at epoch 700).
- SKI will compute forwards in subchain 1 from epoch 201 to 500 and compute backwards from epoch 1 to 200
- In subchain 2, forward computation is carried out from epoch 701 to 1000 and backward computation from epoch 501 to 700.

The entire computation is carried out automatically.

PROCESSING OF KOF CHAINS





15. Interpreting the results

15.1 Initializing SGS and KIS data with a Rapid Static Fix

The Rapid Static fix initializes a SGS and KIS chain. The Rapid Static fix has to be successful (A=Y) for reliable results in the moving part of the chain.

The baseline length for the Rapid Static fix has to be less than the limitation value set in SKI (default = 20 km) and should always be as short as possible. For reliable results the ambiguity resolution has to be successful (A=Y).
For successful ambiguity resolution (A=Y), follow the guidelines for baseline lengths, observation times, number of satellites, GDOP etc.

If the ambiguities are not resolved (A=N), it is very difficult to give an indication of accuracy for both the Rapid Static fix and for the moving part of the chain. The Rapid Static fix will not be reliable and will not be suitable for the initialization of a high-accuracy Stop and Go or True Kinematic chain.

For further information see section 10 of the booklet "Guidelines to Static and Rapid Static GPS Surveying".

15.2 Initializing SGS and KIS chains on a known point

Provided the WGS 84 coordinates of the known point are correct relative to those of the reference receiver, provided that the coordinates are stored in the SKI data base, and provided that sufficient satellites were observed for at least 2 or more epochs (4 to 6 or more epochs are preferable), SKI should resolve the ambiguities (A=Y).

15.3 The Moving Part of SGS and KIS chains

Provided the ambiguities are resolved successfully in the initialization part of the chain, SKI will try to carry forward and resolve ambiguities in the moving part of the chain. If this can be done you will see A=Y. The results should be correct to the accuracies described in section 2 above.
If for some reason SKI cannot carry forward and resolve ambiguities to a minimum of 4 satellites in the moving part of the chain you will see A=N.

As explained in 15.1, if the ambiguities cannot be resolved it is difficult to judge the actual accuracy and the results have to be considered unreliable. They will certainly be outside the accuracy levels described in section 2. The level of accuracy can also be judged by inspecting the sigma values for each coordinate component.

It can happen sometimes that the results show A=N for certain epochs but the sigma values of the coordinate components are small as usual. In this case the ambiguities to a minimum of 4 satellites have usually been transferred correctly, but the ambiguities to new additional satellites could not yet be resolved. Thus SKI shows A=N. This may happen when a new satellite rises or when a satellite was affected by a cycle slip. The results for such points can usually be considered to be correct.

For further information see section 17.1.

15.4 Results of KOF chains

Provided that SKI can resolve the ambiguities successfully, the results panel will show A=Y for all observation epochs. If you see A=N for part of the chain, SKI could not fix the ambiguities for some reason. In this case it has to be assumed that the accuracy of the results are outside the values described in section 2.

Reasons for not resolving the ambiguities can be noisy data, frequent cycle slips, poor geometry, excessive baseline length, or a combination of these factors.

15.5 Time-tagged points

Time-tagged points, which have been taken within a KIS or KOF chain, will show up in the results part of the data-processing component.
In the case where "INSTANTANEOUS" points were captured, the results will show the point id, coordinates, sigma values etc. Coordinates are obtained by linear interpolation between the results from the previous and following epochs.
Points surveyed using "NEXT EPOCH" will show up as individual points. The coordinates refer to the regular epoch at which the point was occupied.

15.6 Inspecting the logfile

If the ambiguities are not resolved (A=N) inspect the logfile. This may indicate the reason why.

Advice on inspecting the logfile for the Rapid Static fix is given in section 11 of the booklet "Guidelines to Static and Rapid Static GPS Surveying".

If the ambiguities cannot be resolved and carried forward in the moving part of the chain (A=N), the reason is almost certainly due to loss(es) of lock. Inspect the logfile for loss(es) of lock at both the reference and the rover.

15.7 Re-computing SGS / KIS / KOF chains in case of difficulties

Look at the logfile. Inspect the azimuth/elevation table and the cycle-slip table for satellites which are frequently lost. Consider de-selecting these satellites in a further computation run.

When processing a long KOF chain, which actually consists of several sub-chains, it can be advantageous to split it into several individual chains by setting appropriate time "windows" in the manual selection screen.

16. Practical advice

High-accuracy Stop and Go, True Kinematic and Kinematic on the Fly surveys offer important advantages in speed and economy. It is important to realise, however, that these methods are more complex than Static and Rapid Static and that it is worthwhile taking certain simple precautions to minimize risks.

16.1 SGS / KIS / KOF: which one to use and when

True Kinematic surveys provide both the trajectory of the roving antenna and discrete points if captured as time-tagged points. This could well be the preferred survey method for digital terrain models etc.
Stop and Go should be used whenever only discrete points are of interest, for instance for detail surveys of any kind.

As SGS and KIS rely on a static initialization they are more robust than KOF. Thus Kinematic on the Fly should only be used whenever a static initialization (either Rapid Static or on a known point) is not feasible, for instance inhydrographic survey.

It is important for the user to realise that these dynamic methods will only work well in areas where proper satellite reception is ensured. An area with numerous obstructions (trees, buildings, bushes, etc.), which will cause frequent cycle slips to more than one satellite, is definitely not a suitable area for dynamic survey methods.

The need for good windows, reliable reference stations, and short baselines has been emphasized.

16.2 Split the work into short chains

Although long chains of 10km and more with many points are feasible, it is preferable to split the work into shorter chains with fewer points whenever possible.

Provided the distance to the reference station is not too long, starting a new chain with a new Rapid Static fix takes little extra time. If a chain fails for some reason, only a short chain has then to be remeasured.
Whenever possible, try to avoid long chains with many points. Try to strike a balance between speed and minimizing risk.

Whenever possible, try to start a new chain as soon as the number of continuously tracked satellites since the start of the chain drops below four.

16.3 Independent checks

In all types of survey work it is sound practice to apply independent checks. Depending on the job and accuracy needed it is well worthwhile applying the same principles to GPS surveying.

For a complete independent check, measure a chain a second time in a different window.

Other possibilities for independent checks include:

- Including known points within a chain.
- Including the last points of a chain in another chain.
- Measuring independent baselines between points in chains.

An extra safeguard plus a partial check can be obtained by using two reference stations instead of one. Two positions for each point or each epoch will be obtained, but they will be based on the same observations at the rover.

16.4 Communication between reference and rover

Keep in mind that a loss of lock at the reference receiver has exactly the same effect as a loss of lock at the rover. Although loss of lock to a satellite is far less likely to occur at a correctly set up reference receiver than at the rover, it cannot be ruled out entirely.

For long chains with only one reference, it can be worthwhile leaving someone with a two way radio to attend the reference receiver and to report any loss of lock. Make sure that the radio used does not affect the receiver. Move away from the receiver before speaking.

17. Stop and Go and Kinematic Surveys of lower accuracy

17.1 Ambiguities not resolved (A=N)

As explained in section 15, if the ambiguities are not resolved it is very difficult to give an indication of accuracy. Multiplying the sigma values for each coordinate by 10 can provide a very rough guide to accuracy.

With the ambiguities not resolved (A=N), it has to be assumed that the accuracies could lie almost anywhere from about 0.2 meter to 1 meter. This will suffice, however, for some applications.

17.2 Kinematic Surveys using differential code only

Kinematic surveys can be carried out using code only. As each differential-code solution is completely independent, the method is much simpler and more robust than high-accuracy kinematic using carrier phase measurements. The advantages are:

- Each differential-code solution (epoch) is completely independent.
- Initialization for ambiguity resolution is not required.
- Any loss of lock affects only the epoch at which it occurs.
- Obstructions are of little consequence.
- It is not necessary to stop after a total loss of lock.

The mission parameters can be as listed in 12.1 with the reference set to STATIC and the rover to KINEMATIC. The operation is as described in 12.2.

Although an initialisation as with True Kinematic (carrier phase) is not required with differential code, it typically takes about 3-5 minutesof continuous tracking of available satellites befire the effects of code smoothing become apparent. Therefore, it is better to wait and track satellites for 3-5 minutes before pressing MEAS after starting the System or after a complete loss of lock.

It is not necessary to stop after a total loss of lock due to an obstruction. Note however that it will take 3-5 minutes of continuous tracking until the position reaches it's optimum accuracy again.

Instead of using a KIS mission, differential-code operation can also be carried out by using KOF. This works for both single and dual frequency equipment. In this case no initial point has to be occupied to start the chain.

SKI can process KOF "code-only" data, even if the AROF option is not installed.

With all Leica GPS Sensors, the code measurements taken on either L1 only or on both L1 and L2 frequencies are smoothed with the carrier phase.

With the SR260/261 and the SR299/299E the C/A code-measurement accuracy on L1 is about 45cm (rms). The P code-measurement accuracy on L2 is about 20cm (rms).

With the SR9400 and the SR399/399E the C/A code measurement accuracy on L1 and the P code measurement accuracy on L2 are about 10cm (rms).

If the P code is encrypted, the SR299/299E switches automatically to a proprietary code-aided squaring technique to track L2 carrier phase. One of the advantages of this technique is that carrier-phase-smoothed code measurements are still available on the L2 frequency. The code-measurement accuracy on L2 is about 25cm (rms) even when the P code is encrypted!

It will be obvious that it is always preferable to use the code on L2 when processing code measurements with SR299s.

If the P code is encrypted, the SR399/399E switches automatically to a proprietary code-aided tracking technique to track L2 carrier phase. One of the advantages of this technique is that carrier-phase-smoothed code measurements are still available on the L2 frequency. The code-measurement accuracy on L2 is about 10cm (rms) even when the P code is encrypted!

SR299/299E/260/261

In Static Survey mode, processing about 1 minute of differential code observations on L2 will give baseline accuracies of about 0.5 meter (rms). L1 data will give accuracies of about 1 m (rms).

In Kinematic Survey mode, processing code observations on L2 with SKI software will give baseline accuracies of about 0.5 meter to 1 meter (rms). L1 observations will result in baseline accuracies of about 1m to 2 m (rms).

SR399/399E/9400

In Static Survey mode, processing about 1 minute of differential code observations on L1 will give baseline accuracies of about 0.3 meter (rms).

In Kinematic Survey mode, processing code observations with SKI software will give baseline accuracies of about 0.3 meter to 0.5 meter (rms).

In order to achieve these accuracies with differential code, it is important to take observations in good windows to at least four satellites.

Good window	4 satellites GDOP < or = 8
Ideal window	5 or more satellites GDOP < or = 5

Differential code provides an easy, reliable technique for both Static and Kinematic Surveys.

Differential code is ideal for those applications for which a robust GPS measuring technique is more important than the highest accuracy.

For more information on code-only operation, for instance in GIS applications, please refer to the booklet "SR260 and GIS-SKI".

ACHIEVABLE ACCURACIES

Achievable accuracies (rms) for Stop and Go, Kinematic, Kinematic on the Fly.

Carrier phase Ambiguities resolved. A = Y	Position:	1 to 3cm + 1ppm
	Height:	2 to 4cm + 1ppm
Carrier phase. Ambiguities not resolved. A = N	About 0.2m to 1m	

Differential code SR299/SR299E/SR260/SR261

on L2	About 0.5m to 1m
on L1	About 1.0 to 2 m

Differential code SR399/SR399E/SR9400

on L1 or L2	About 0.3 to 0.5m

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