A2-3DA

Saturn Navigator

by Wes Huntress

for the Apple II

(48K memory, Applesoft required)

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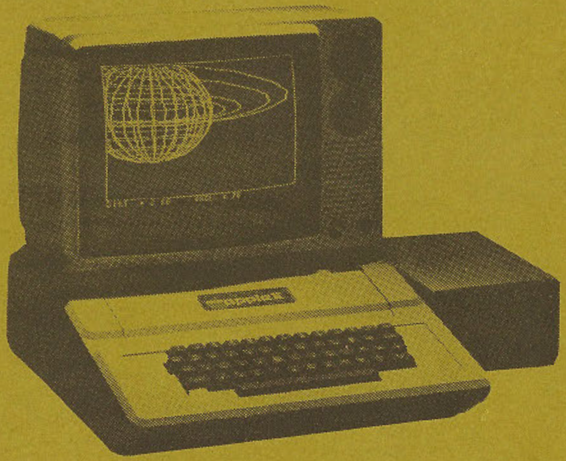

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Communications Corp.

A2-3DA SATURN NAVIGATOR

By Wes Huntress, Scientist
Jet Propulsion Laboratory
Pasadena, CA

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Sublogic Communications Corporation
713 Edgebrook Drive
Champaign, IL 61820

First Edition
First Printing

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LOADING THE PROGRAM

Boot your system with the Saturn Navigator disk in drive 1. The program will load itself and begin to run automatically. After this point DO NOT REMOVE THE DISK FROM THE DRIVE.

Disk Errors

In the event of a disk error, one of two things might happen:

1. Your Apple II will state DISK ERROR followed by two characters. (DISK ERROR_ _) Please copy down both characters when referring this problem back to us.

2. Your disk in use light stays on and the disk keeps spinning. This is a system problem and will not generate an error message.

In addition to disk errors, if your computer doesn't have Applesoft ROM the program will not load.

Sublogic Communications Corporation warrants all media for a period of 6 months from the date of purchase. In addition, Sublogic Communications Corporation will replace any media that is out of warranty at a minimal charge. Sublogic Communications Corporation will extend this replacement service for a period not less than 10 years after purchase.

If you wish to return defective cassettes or disks, please return the MEDIA ONLY.

We have established an efficient repair/replacement system which promises long run benefits to you. Returning the manuals will complicate the system and will raise shipping costs.

*Example; replacement charges April 1, 1982: $5.00 for a disk.

INTRODUCTION

The programs on this diskette are designed to illustrate how spacecraft are maneuvered from one planet to another. The laws of celestial mechanics are demonstrated in a game-style format using high-resolution graphics and 3-D animation. The object of the simulation is to navigate a spacecraft from earth orbit to Saturn orbit, and finally to rendezvous with a space station orbiting Saturn between the planet and rings. The user functions as pilot and navigator to plot his course and set up maneuvers.

The earth-Saturn voyage must be accomplished within the limit of the total amount of fuel available. Both fuel consumption and time may be used as factors in evaluating performance. Shorter travel times require higher velocities, leading to higher fuel consumption. At various points throughout the flight you may find yourself in a situation where it is impossible for you to successfully continue, due to either poor position or lack of fuel. Under such circumstances your only remedy will be to start over.

The trip from earth to Saturn is made in four stages:

1. TRANSORBIT flight between earth orbit and approach to Saturn

2. APPROACH to Saturn and injection into initial Saturn orbit

3. ORBIT of Saturn and orbital maneuvers to put the spacecraft into an equatorial orbit inside the inner edge of the rings and above the planet

4. RENDEZVOUS with the Saturn orbital station in a near-Saturn circular orbit

Saturn Navigator is a complex simulation which uses sophisticated calculations and a large Saturn data base to simulate interplanetary flight as realistically as possible. The accuracy and competence with which you perform each maneuver will affect your later situation. For example, you can maneuver yourself into a transorbital position where it becomes nearly impossible to achieve a successful approach trajectory.

It may take many attempts before you are able to successfully complete a rendezvous with the Saturn orbital station. While you might be anxious to run through the entire mission, we recommend that you initially concentrate on improving your transorbital maneuvers (and their effects on your approach). Remember, an efficient orbit insertion will ensure more fuel remaining for subsequent orbital and rendezvous maneuvers.

Please read this manual thoroughly in order to understand how to properly navigate your spacecraft. Your flight to Saturn may require some patience, but just consider how long it would take in actuality.

GOOD LUCK AND HAPPY NAVIGATING!

TRANSORBIT

Step #1: Select earth-Saturn trajectory

Hit any key to begin. Input a trial transorbit injection velocity. The orbital velocity of the spacecraft is already 29.8 km/s. Trial and error will show you what range of velocities are necessary to get you out as far as Saturn. Throughout these programs, energy is expressed in velocity units, i.e. km/s. This is the unit of energy required to accelerate or decelerate your spacecraft by 1 km/s. You start in earth orbit with 30 km/s of total available energy.

If you are going to be judging performance in part by total travel time, remember that you will have to be careful to conserve fuel and maneuvers after a fast Saturn trip in order to have sufficient fuel for Saturn orbital and rendezvous maneuvers. You will be shown the approximate travel time and Saturn approach velocity after your trial flight path has been plotted. You will then be given four command choices:

COMMAND #1: Reject trial flight path, try another

COMMAND #2: Display view of Saturn on approach from this flight path

COMMAND #3: Select this trial flight path, initiate maneuver sequence

COMMAND #4: Clear screen of old trial orbits

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If you forget these commands, or any of the commands in various command lists throughout these programs, press the space bar (or any non-command key) for help and a command menu will be presented.

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Command #2 allows you to see what aspect the rings will present for the trial approach to Saturn. This is important for determining your aim point and initial orbit insertion at Saturn. The ring aspect will be slightly different for different arrival times since Saturn will be at a different point in its orbit. The approach sun angle is the Sun-Saturn-Spacecraft angle measured past Saturn local noon. The approach ring angle is the angle between the rings and approach flight path.

Once you have chosen a flight path, the maneuver sequence starts. A count-down to engine firing is started. The engine is fired tangent to the spacecraft's earth orbital path to give your selected injection velocity. The injection is timed for a particular earth-Saturn alignment so that the spacecraft will cross Saturn's orbital path when the planet is present at that position.

Step #2: Mid-course maneuvers

a. First mid-course opportunity

After injection into an earth-Saturn trajectory, you will be given four to five opportunities for mid-course maneuvers. This is accomplished by adjusting the aim point on a plane projection of the planet. The computer will calculate the required velocity change and execute the maneuver.

The first mid-course opportunity is unique. The cross on the screen marks the point in the approach plane where the spacecraft would pass Saturn if the planet had zero gravity. The box on the screen shows the actual point the spacecraft will pass due to the influence of Saturn's gravity. (Fig.1).

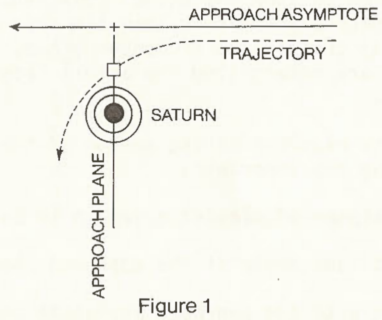

Figure 1

If you choose to retarget the aim point, use the indicated keys to move the zero gravity point (cross) so that when the approach plane crossing is recalculated by the computer, the square will be at the point you wish the spacecraft to pass. The aim point is moved using the same keys as are used to move the cursor in the auto-start ROM screen editing mode:

J:	Move aim point left
K:	Move aim point right
I:	Move aim point up
M:	Move aim point down
RETURN:	Finished

Use the REPT key for consecutive moves over long distances.

Saturn's aspect will change as you retarget the aim point. You must target the aim point to the right of (behind) Saturn in order to insert the spacecraft into a prograde orbit when you arrive. The Saturn station with which you must rendezvous is in a prograde orbit.

b. Subsequent mid-course opportunities

For all mid-course opportunities subsequent to the first, the cross is used to show the actual point the spacecraft will cross the approach plane rather than the zero gravity crossing. The zero gravity crossing is no longer shown. When you retarget the cross, you are retargeting the actual Saturn approach plane crossing point.

The numbers reported at the bottom of the screen after each retargeting are important:

RMIN: Distance of closest approach in Saturn radii

INCL: Latitude angle at the approach plane crossing

RANG: Angle to the approach asymptote presented by the rings

DISP: Angle from approach plane to point of RMIN

DVX: Delta-V required in x direction

DVY: Delta-V required in y direction

These parameters are illustrated by Figures 2-4.

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The point of closest approach, RMIN, is not at the approach plane crossing. Saturn's gravity bends the orbit and moves the point of closest approach inward and around to the rearward of the approach plane crossing an amount which depends on the approach velocity and the "impact parameter" b, or the asymptotic (zero gravity) miss distance. See Fig. 4.

****

You must pay close attention to RMIN and DISP in order not to target for impact of Saturn when targetting between the rings and planet, or for impact of the rings themselves when targetting outside the rings. Targetting for planetary impact will be rejected, but targetting for ring impact will be accepted.

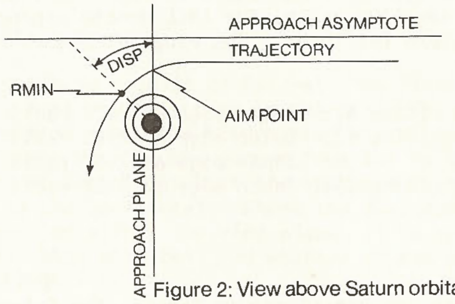

Figure 2: View above Saturn orbital plane

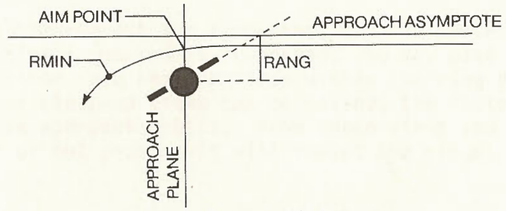

Figure 3: View in Saturn orbital plane

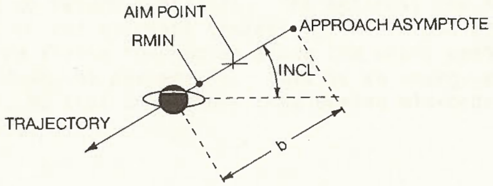

Figure 4: Approach view

Negative values for RANG denote an approach from below the ring plane and negative values for INCL denote approach plane passage at southern latitudes. The rings of Saturn and their boundaries are:

Outer Ring	(Ring A):	Outer edge at 2.27 radii
Middle Ring	(Ring B):	Outer edge at 2.00 radii
		Inner edge at 1.50 radii
Inner Ring	(Ring C):	Inner edge at 1.22 radii

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Note that as you get closer to Saturn, the Saturn approach plane image gets larger, the target area gets smaller, and the post-maneuver accuracy improves.

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APPROACH

Approach Plots

Now you have made it to Saturn! The first thing that happens is that you are shown an overhead plot of your approach trajectory from above the Saturn ring plane, as in Fig. 2. The approach plane bisects the screen from top to bottom through the center of Saturn, so that the approach asymptote is parallel to the horizontal. Where the approach trajectory crosses or lies within the ring plane, it is surrounded by a red box. This will tell you whether or not you will impact the rings.

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If you impact any of the three rings, the spacecraft will be destroyed!

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Plot Commands

At the request for a command, hit the space bar for a menu. At any time a command is requested, you may plot the current orbit either from above or from within the ring plane of Saturn. Normal or close-up views can be called; the latter important for close approach orbits. From these views you can determine whether or not your orbit will impact the rings.

Approach Maneuver Commands

Change approach velocity

There are two maneuvers which you can set up before the approach to Saturn continues. The optional one is a final adjustment to the approach trajectory. This you are allowed to do only by firing the engine along the orbit path to speed up or slow down the spacecraft. This is an energy-expensive maneuver, so that trajectory trim during mid-course is to be preferred.

After this command is selected, follow the instructions given and input a new approach velocity. For reference, the present approach velocity is given along with RMIN. Hit return to bail out of this selection. If you input a new approach velocity, a new approach trajectory will be plotted and you will be shown how much fuel would remain after the maneuver. When prompted for a command, hit the space bar for help if you need it. You can plot the new trial orbit in one of the four available perspectives. Finally, you must accept or decline the approach change (#7 or #8).

If you decide to make the approach change, answer "Y" when asked if you want to initiate the engine burn. The maneuver will take place immediately.

Set orbit insertion

You must set up an orbit insertion maneuver before approach can continue. The maneuver is not performed immediately, but is always programmed for a retrograde burn just at closest approach (RMIN). To set up the maneuver, input a distance in Saturn radii for the initial orbit extremity (periapsis or apoapsis) opposite the closest approach point (Fig. 5).

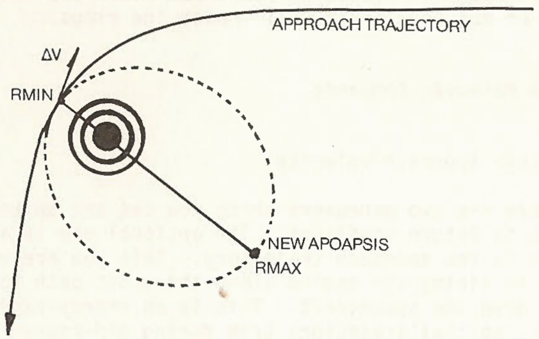

Figure 5: Initial orbit

Once the trial insertion orbit has been chosen, the orbit will be plotted. You will be shown where it crosses the ring plane (red boxes) and the fuel usage for the proposed maneuver. At the command prompt, you may replot the orbit from another perspective, reject the orbit, or choose it. If you accept the trial insertion orbit, you will be asked if the approach trajectory is OK, giving you one final chance to bail out. Once you accept the orbit insertion maneuver, the approach to Saturn will resume irrevocably, and you will not have another chance for maneuvering until just after the orbit insertion maneuver has occurred.

Restart/Exit

To bail out of the program, hit command key #9. You will be given a choice to restart from the approach, to restart from earth orbit, or to exit to Applesoft. If you crash into the rings during the approach, you will be given a chance to redeem yourself with another try.

Exterior View

After you have set up the orbit insertion maneuver, the approach run will begin automatically. You will be treated to an out-of-the-window 3-D projection of your approach to Saturn. The exterior camera is programmed to point not along your trajectory, but to the right limb when approaching the planet, and to the left limb when receding from the planet.

Orbital Changes

At any time after orbit insertion, hit a key to begin the process of working your orbit into one entirely inside of the inner edge of ring C and in the ring plane. If you haven't entered this mode before reaching the extreme of your initial orbit, it will happen automatically.

ORBIT

Global Commands

On initial entry into the Saturn ORBIT navigation routines, you are placed in the global command mode with six command choices:

#1 STATUS: Will advise you of the periapsis (RMIN), apoapsis (RMAX), and inclination (INCL) of the orbit, the amount of fuel remaining and the total travel time. Hit any key to return to the global menu.

#2 ORBIT PLOT/CHANGE: Enters the orbit plot/ change mode.

#3 CONTINUE: Exits global command mode and continues movement on the orbital path with exterior view. Hit any key while in orbital cruise to access the global command list.

#4 INITIATE RENDEZVOUS: If you have achieved an orbit in the ring plane inside the innermost ring, use this command at your earliest opportunity to initiate rendezvous with the Saturn station.

#5 RESTART: Gives you the option to bail out and start over from your initial Saturn orbit, from your initial Saturn approach, or from the beginning in earth orbit. Hit a non-option key to return to the global command mode.

#6 QUIT: Back to Applesoft.

Orbit Plot/Change Commands

Orbit plot commands

These are the same as those used during approach. Either the current orbit or a new trial orbit can be plotted in any of the four perspectives.

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The reference coordinate system has been changed in the ORBIT routines from that used in the APPROACH routines. For APPROACH, the incoming trajectory asymptote is used as the horizontal axis. Now that you are in Saturn orbit, and the approach trajectory is no longer important, the horizontal axis through the planet (blue line for overhead plots, ring plane for in-plane plots) is now the line of intersection between the orbit plane and the plane of Saturn's rings. Where the orbit crosses this line, it is crossing the ring plane.

The ORBIT coordinate system is more convenient to show where the ring plane crossings are for in-plane views. Unlike the APPROACH coordinate system, for ORBIT in-plane views the orbit crosses the rings in the plane of the screen. The in-plane view is a cross-section through the planet at the line of intersection between the orbit plane and ring plane. This line is also the blue horizontal line in overhead plots.

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Orbit Change Commands

Change Periapsis/Apoapsis

To change the periapsis (low point) or apoapsis (high point) of your orbit, select this command. You will first be shown an overhead plot of your present orbit. For an elliptical orbit, select which orbit extremity you wish to modify and then respond with a new trial value. Hit a non-numeric key to bail out. The listed orbit parameters will be changed, the new orbit plotted, and the maneuver data listed. You may now plot the new orbit in some other perspective (commands 1-4) in order to check the ring plane crossings. These are not boxed as on APPROACH since the ring plane crossings are now always at the center horizontal. To select or reject this new orbit, use commands #7 or #8 respectively. If you reject the trial orbit you will bounce back to the command menu. If you accept the orbit you still have a chance to bail out by not initiating the orbit change sequence at request. If you accept the request, the maneuver sequence is loaded and you are returned to orbit cruise.

Orbit periapsis/apoapsis changes are made in the most fuel-economical way. For elliptical orbits, changes are made by an engine burn in the appropriate direction of motion applied along the orbit path at the opposite extremity of the orbit. For example, to raise periapsis, a burn is made at apoapsis along the direction of motion as in Fig. 6.

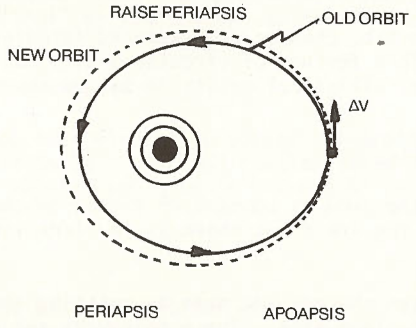

Figure 6

To lower the apoapsis, a burn is made at periapsis opposite to the direction of motion as in Fig. 7.

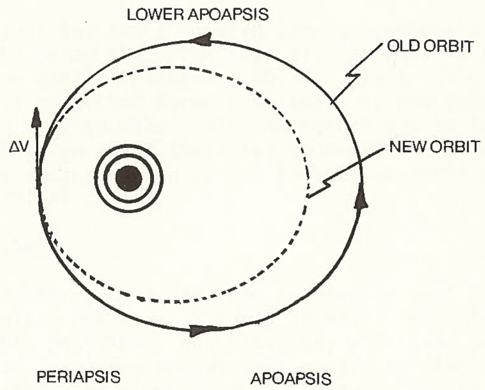

Figure 7

You may interrupt cruise at any time in order to set up a new orbital maneuver. For an elliptical orbit the maneuver sequence will be stored in the computer and executed when the spacecraft reaches the appropriate point in the orbit. To cancel a maneuver sequence in the computer, hit any key while in orbital cruise.

From circular orbit, changes are executed immediately upon return to cruise. This feature of circular orbits can be used to rotate the axis of elliptical orbits in Saturn space.

Change Inclination

Works exactly the same as command #5 except to change the orbit inclination. You are first shown an in-plane view of the current orbit.

Orbit inclination changes are made by rotating the orbital plane about its ring-plane axis. These maneuvers are performed at one of the two points where the orbit crosses the ring plane, usually at that point farthest from Saturn.

RENDEZVOUS

Once you have successfully initiated RENDEZVOUS, the computer will generate an overhead view of the in-plane orbits of both the Saturn station and your spacecraft. Each will then proceed on orbit until you stop it by pressing a key to enter the command mode. From the command mode you can call for a rescue (chicken!) or you can set up for an orbital maneuver.

Set-up Orbit Change

Once you have elected to change the orbit, your present orbital position is frozen and another image of the spacecraft appears one orbital position in advance of your present position.

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You must plan for orbital maneuvers in advance. Stop orbital cruise and set up your maneuver at least one orbital position in advance of where you wish the maneuver to take place.

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You can project the orbit forward (and subsequently backward again) by using the arrow keys as indicated to pick the spot where you want the maneuver to take place. The station orbit is also projected forward so that you can judge what maneuver you need to make. Hit the return key to indicate the orbital position on which the trial maneuver is to take place, or hit the escape key to cancel the change orbit routine and go back to orbital cruise.

Selecting a Maneuver

After hitting the return key from the set-up mode, answer "Y" to the "Calculate new orbit?" query in order to plot a new trial orbit at this position. Any other key will send you back to the set-up mode. You are now given a choice to circularize the orbit or to set-up your own maneuver. If you select "Auto-circularization" the computer will calculate the burn direction and velocity change necessary, and report the resulting orbit parameters and fuel remaining after the maneuver.

If you do not wish to circularize the orbit, the computer will ask you first to input an angle from the present velocity vector for DELTA-V, or the direction in which the new impulse is to be applied. Second, the computer will ask you for DELTA-V, or the incremental velocity you wish to apply in your specified direction. Give a non-numeric response to either of these requests to bail out. For numeric input, the new orbit parameters and fuel remaining after the maneuver are displayed, and you are asked if these parameters are what you were looking for. If not, bail out with an "N" answer. If you give an affirmative answer, then the new trial orbit will be plotted.

Do not worry if your new orbit crashes into the rings or planet. You may still select it knowing full well that you will have to change it before disaster occurs. Selecting such an orbit is sometimes desirable in order to complete rendezvous.

You are next asked if you want to project this trial orbit forward. If you do, it works just as before to move the spacecraft and station forward (or backward) in their orbits, with the spacecraft moving on the new trial orbit. This feature will help you to decide if the new trial orbit achieves what you want. Hit escape to go back to the trial orbit start.

If you want the new orbit then select it, and the data will be stored in the computer for later execution at the selected position in the orbit. You will then be bumped back to orbital cruise. If you do not select the new orbit, its plot will be erased and you will be given the opportunity to select a new trial orbit.

Achieving Rendezvous

Use the above procedures in order to manipulate your orbit so that at one point the spacecraft arrives at the orbit of the Saturn station for auto-circularization just at the time that the Saturn station is present at that position. You then will have achieved rendezvous and will have completed your trip! From here you can elect to start again. If you run out of fuel before achieving rendezvous, then call for a rescue.

GLOSSARY OF TERMS

APOAPSIS: Farthest point from the planet in an orbit.

APPROACH ASYMPTOTE: Line of approach in absence of any gravitational perturbations (bending).

APPROACH PLANE: Plane perpendicular to the approach asymptote and passing through the center of the planet.

DELTA-V: Change in velocity. Velocity increment.

INJECTION VELOCITY: Delta-V required to place spacecraft on a trajectory from earth to Saturn.

ORBIT PLANE: Plane surface containing the orbit.

ORBITAL INCLINATION: Angle of the orbit plane to Saturn's equatorial (ring) plane.

ORBITAL VELOCITY: Velocity along the direction of motion in any orbit.

PERIAPSIS: Point of closest approach along an orbit.

PROGRADE: In the same direction as planetary rotation.

RETROGRADE: In the direction opposite to planetary rotation.

RING PLANE: Plane surface containing Saturn's rings. Same as Saturn's equatorial plane.

TRAJECTORY: Flight path or orbit.

TRANSORBIT: Flight across or between orbits, as in flight from earth orbit to Saturn orbit.

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Communications Corp.
713 Edgebrook Drive
Champaign, IL 61820
(217) 359-8482