computer software needed to implement EICA is in the public domain. Such software has been used by the Jet Propulsion Laboratory to develop, on behalf of the National Aeronautics and Space Administration (NASA), an auction mechanism to assign scientific resources on NASA's planned space station. First developed by the California Institute of Technology, this software, which is entitled the Adaptive User Selection Mechanism (AUSM), permits bidders to bid for different packages of such scientific resources. AUSM is "iterative" in that it allows bidders to improve their bids in response to the bids submitted by others. In the space station application, each new or increased bid is tentatively accepted if it yields more revenue than the current set of tentatively accepted bids that needs to be displaced to free the required resources. A more advanced version of AUSM (i.e., AUSM with standby queue) includes a mechanism for allowing bidders the opportunity to coordinate their bids in an attempt to avoid the free-rider problem.[97] Finally, AUSM terminates the auction at some time unknown to the bidders and all tentatively accepted bids become contracts. In terms of hardware, AUSM requires a standard micro-computer for operation.

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[97] For an economic analysis of the performance characteristics of AUSM, see J. Banks, J. Ledyard, & D. Porter, Allocating Uncertain and Unresponsive Resources: An Experimental Approach, 20 Rand J. of Econ. 1-25 (1989).

AUSM raises some implementation issues. AUSM was developed to assist NASA in making more economically efficient resource assignments on its planned space station. Because of the unique nature of that application, some changes to the AUSM software must be made before it can be used to assign PCS licenses, although we believe that such changes are minor. In addition, because AUSM uses a computer to evaluate bids and determine the optimal assignment, bids must be submitted using a computer terminal. For the Commission's purposes, one way to permit such bidding would be to allow bidders to submit bids from different locations (i.e., either from different bidding rooms at the Commission or from remote locations). AUSM is designed to handle such a bidding submission procedure. Regarding remote bidding, there are numerous ways of designing, on a temporary basis, a secure, nationwide, bidding network. However, because some bidders may not have access to a computer terminal, we recommend that the Commission set aside a room with numerous terminals where such bidders can submit bids. The application fee that bidders have paid when filing applications for PCS licenses can be used to pay for such terminals. Implementation issues are discussed more fully in Attachment 2.

Finally, we have presented EICA as a mechanism for facilitating the efficient geographic aggregation of PCS licenses, since it seems clear from experience with cellular and other forms of land mobile services that such aggregation is both

important and common for the wireless industry. However, the economic efficiency of PCS auctions would be enhanced if it were possible to implement an EICA that is capable of handling the combinatorial features of spectrum aggregation as well,[98] for the entire United States. With the appropriate modifications to its software, AUSM can be used to implement such an EICA.[99]

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[98] The Commission permits PCS licensees, with some exceptions, to aggregate up to 40 MHz in any geographic area. See Amendment of the Commission's Rules to Establish New Personal Communications Services, Second Report and Order, Gen. Docket No. 90-314, FCC 93-451 para. 61 (released Oct. 22, 1993).

[99] Programming experts familiar with AUSM have informed us that such a modification presents no technical difficulties.

Attachment 2

EICA Implementation Issues

The following describes how the Commission and bidders would use an electronic iterative combinatorial auction (EICA) in conducting the auction for PCS licenses.

I. The Process

Step 1. Pre-Auction

Qualified bidders, as determined by the Commission, would receive a password prior to the auction. The passwords could be assigned to distinguish among bidders that are eligible for different types of licenses.[1/] In addition, the Commission could, if it were particularly concerned about bidders' abilities to pay, issue each bidder a total bidding limit based on financial information disclosed in the application process.[2/]

1/ For example, in the auction, the computer software that analyzes bids could accept bids for set-aside licenses only from bidders with designated entity passwords. Similarly, passwords could be used to address eligibility of cellular bidders.

2/ From an economic perspective, a total bidding limit would be preferable to a bidding limit on individual licenses as a test for ability-to-pay because bidders would not have to pre-commit to participation in auctions for only certain licenses. If a bidder values each of a group of licenses roughly equivalently, and demands only a handful of such licenses, it should be allowed the flexibility to respond to market forces to satisfy its demand. If the Commission's concern is credit-worthiness, a total spending limit is a flexible way to achieve its goal.

In addition, in the days leading up to the auction, the Commission could conduct practice bidding rounds, open to the public, to familiarize bidders with submitting bids by computer.[3/]

Step 2. Day of Auction

On the day of the auction, bidders need access to a computer terminal. These terminals could be located at the Commission's headquarters in Washington, D.C.,[4/] in other governmental sites within Washington, D.C., at the Commission's 35 field offices around the United States, or at remote locations. Remote computer terminals must be connected to the Commission's computer through, for example, modems. Remote terminals may, however, raise concerns about bidders' true identities (i.e., computer hackers could mimic qualified bidders). If all terminals were located at Commission offices or other controlled facilities, each bidder's identification could be checked every time he or she entered the bidding room. Once at a connected terminal,

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3/ Practice bidding would operate much like laboratory experiments on competitive bidding. Participants would be given hypothetical valuations for imaginary PCS licenses. Given these valuations, subjects would submit bids for the licenses, and attempt to maximize the difference between their valuations and the price paid for the licenses they obtain.

4/ Of course, clustering too many bidders at the Commission could also be difficult. If this alternative was adopted, bidders could share terminals according to a pre-specified rotation. For example, six bidders could share one terminal. Each bidder would be assigned the same ten minutes within each hour. These allocations could be traded among the six bidders to afford greater flexibility.

bidders would log into the Commission system and submit their pre-designated passwords.

Step 3. Submitting Bids

After successfully logging into the Commission system, bidders would be ready to submit bids. Bids must indicate the desired spectrum block or blocks (A,B,C,D,E,F,G), the desired geographic area or areas (MTA or BTA numbers), and the amount of the bid. For example, suppose a bidder wants to submit a combinatorial bid for blocks C and D in BTAs 10, 11, and 12. The bidder would enter the equivalent of the following: CD, B10,11,12 and the amount of the bid. Bidders could submit bids for multiple combinations of PCS licenses.[5]

Step 4. Bids Sent to Computer

All bids submitted by participants are sent to the Commission's computer. Using a modified version of the AUSM (Adaptive User Selection Mechanism) software, the computer[6] sorts through all bids, applies the algorithm described in Attachment 1, and finds the current "winning" allocation. All bids that are part of this allocation are referred to as

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5/ The Commission conceivably could limit the number of outstanding bids per bidder to avoid congestion problems. However, conversations with experts familiar with software used for such purposes suggest that this is not likely to be a problem.

6/ The California Institute of Technology uses an IBM RS 6000 to conduct its experiments employing AUSM.

"tentatively accepted," and could be posted on an electronic scoreboard that bidders could access on their terminals.

Step 5. Reports Sent Back To Bidder

After processing the bids and computing the current "winning" allocation, AUSM instructs the Commission's computer to send each bidder the following information: which of its bids have been tentatively accepted (i.e., are part of the "winning" allocation), which bids have been rejected, how much its rejected bids must be improved to become part of the tentatively accepted allocation, and a list of the remaining tentatively accepted bids.

Step 6. Bid Improvements

Each bidder has the option to improve its rejected bids in response to the bid improvement information supplied by AUSM. AUSM does not, however, permit bidders to withdraw tentatively accepted bids. AUSM is, therefore, an ascending-bid mechanism in that bids can never go down.

Given these new, higher bids, AUSM computes a new "winning" allocation as in Step 4 and reports information back to bidders as in Step 5. Because steps 4, 5, and 6 are repeated over and over, the auction is said to be "iterative."

Step 7. Stopping Rule

It is important that bidders not know exactly when the auction will end.[7] If bidders knew, they might under-reveal demand throughout the auction in an attempt to obtain the item at a "low" price just before the end of the auction. The possibility that the auction could end at any round provides bidders an incentive to reveal their demand more aggressively throughout the auction.

Because AUSM is an ascending-bid mechanism, any additional bidding activity implies increased revenues. The Commission should not, therefore, stop the auction during a flurry of bidding activity. As a practical matter, it may take several days for bidding activity to die down. Once activity has died down, the Commission could terminate the auction.[8] After terminating the auction, the Commission would certify as winners

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7/ Like English auctions, which are open-ended and thus terminate on short notice when the auctioneer determines bidding is "complete," this auction would be stopped at the discretion of the Commission.

8/ The Commission could have a pre-determined stopping rule known only to it based on bidding activity. For example, after bidding activity had died down sufficiently, the Commission could determine the stopping time in a random fashion. Alternatively, it could send notice to bidders of the impending close of the auction in a manner reminiscent of the "going, going once, . . ." variety employed by oral auctioneers. Of course, the Commission would then have to determine what is a sufficient amount of bidding activity to keep the auction open after such an announcement.

We note also that if bidders share terminals, it will likely take more time for bidding activity to die down.

those bidders that submitted the last tentatively accepted bids. The deposit, petition to deny, and payment requirements would be the same as those proposed by the Commission in its Notice.

II. Insuring Integrity of the System

The integrity of an electronic bidding system is an important issue in several ways. First, the computer algorithm selected by the Commission should be publicly available for analysis. Second, the operational integrity of the system must be assured. For example, the Commission must make certain that any remote bidding is performed by authorized users.[9/] Moreover, bidders must have confidence that the bids that they enter on their terminals are being accurately recorded by the software, and that the algorithm is actually computing properly. To provide such assurances, all bidding activity should be continuously recorded in a computer file. This file should be available for inspection by Commission officials, and the Commission could make it available to all bidders.

For a bidder particularly concerned about whether its bidding activity was accurately recorded, a computer file containing only its bidding activity could be made available. Additionally, in the event of a technical problem, a complete record of all bidding activity makes it possible to resume the auction at the point at which it left off.

9/ See discussion supra at p. 2.

A more general concern potentially confronting the Commission is how to assign licenses in the event that a bidder cannot make payment for a license, wants to retract a bid, or is disqualified for other reasons. As noted above, if the Commission could define bidding limits based on letters of credit, the non-payment problem could be addressed. In addition, the Commission could require, as a condition to participation in the auction, that bidders submit a percentage of their bidding limit as an up-front payment.[10/] This amount would be returned if a bidder obtained no licenses, or partially refunded if the amount was greater than the sum of its bids on licenses it did obtain. If, however, a bidder could not make full payment upon award of the license, its up-front payment would be forfeited. A combination of these measures could keep disqualifications for non-payment to a minimum.[11/]

In those instances when disqualification or withdrawal did occur during or after the bidding, the Commission has alternatives. It could reopen electronic bidding only for "forfeited" properties after such properties are identified. Alternatively, suppose the disqualified bidder had won the auction for spectrum block A with a combinatorial bid for MTAs

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10/ This is similar to the approach in the Notice, para. 172.

11/ Disqualifications for other reasons (e.g., foreign ownership restrictions) could be largely eliminated if the Commission examined bidders' qualifications adequately prior to the auction.

20, 21, and 22. The algorithm could search through all possible bidding combinations for these MTAs, and find the "second best" allocation. Of course, this method is imperfect because it would not permit searching through combinatorial bids that involved MTAs 20, 21, or 22 plus other MTAs.[12] Although there might be some efficiency losses because bidders would be unable to submit new combinatorial bids for forfeited and non-forfeited licenses, such losses are almost certainly a more attractive option than attempting to reopen bidding on all licenses.

12/ There is, of course, the private marketplace for those bidders looking to create such a combination.