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Report 1A: Auction Design Enhancements for Non-Combinatorial Auctions

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AUCTION ENHANCEMENTS

In this initial report, we evaluate a number of possible enhancements to the FCC auctions. We consider only changes to the current auction rules that stay within the basic format of the simultaneous multiple round auction for individual licenses. This report summarizes and extends our e-mail exchanges with FCC staff on this topic. A subsequent report will cover auctions with combination bids.

Overall, the FCC spectrum auctions have been an enormous success. However, there are two design goals in the auction where important improvement can be achieved within the basic rules structure. These are restricting collusion among bidders and reducing the time taken to complete the auction. This report focuses on enhancements that help to achieve these two goals. Some of the suggested changes also streamline the auction process so large auctions can be conducted more quickly without sacrificing efficiency.

Although some of our suggestions — particularly those about closing rules — work both to restrict collusion and to speed the auction along, we have grouped the recommendations into two categories according to our assessment of the main reasons for the suggested change.

Avoiding Collusion

The first three suggestions, truncating the bids to three digits, limiting the use of bid withdrawals, and modifying the closing rule are intended primarily to reduce the opportunities to collude. We agree among ourselves that the first two kinds of changes are clearly desirable. We have some disagreement among ourselves about the third type of change and how it is best implemented.

TRUNCATE BIDS TO THREE DIGITS

One way in which bidders have attempted to coordinate their bidding is by signaling information in the last few digits of their bids. For example, a bidder can point to a market or bidder by putting a market or bidder number in the trailing digits of its bid. This practice has been observed in each auction. Bid signaling was especially common in the DEF auction and, indeed, one bidder filed a formal complaint about this practice. The importance of this mechanism is uncertain, as bidders and their advisers appear to have had difficulty making sense of the coded bids, and even when the codes were understood, competition was not necessarily reduced.

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Since signaling through trailing digits threatens the effectiveness of the Commission's rules against direct communication among bidders during the auction, the opportunity to signal by using trailing digits should be eliminated. A simple and virtually costless way to achieve that goal is to limit bids to three significant digits. Under this rule, an entry of $123,546,789 would be truncated to $123,000,000 by the bid submission software. Using three digits gives bidders ample freedom to express preferences through higher bids, and yet eliminates the bid-signaling problem. With three significant digits and a 5% bid increment, rounding the minimum bid, whether up or down or to the nearest eligible bid always results in increments that are between 4% and 6%. That is a small enough change to have no serious effect on the pace or efficiency of the auction.

With three digits, it is almost impossible to communicate a market or bidder number in the bid. Most market and bidder numbers are two or more digits. If one wanted to signal market 23 and the bidding is at 100,000,000, one could bid 123,000,000. But notice how unclear a signal this is without the leading zeros to indicate the beginning of a code (as in 100,000,023). In this context, $123 million is a reasonable bid, and bidders will not be able to distinguish a code bid from a regular bid. Even when allowed to make bids like 100,000,023, bidders (and their advisers) were having a hard time making sense of code bids.

A similar alternative would be masking bids; that is, to report bids rounded to three digits. This is an inferior option, since there is a loss of transparency for essentially no gain. Under masking it is no longer possible for bidders to check that the auction rules are being followed. One of the strengths of the current FCC system is its full transparency. This should not be given up unless there are good reasons for doing so. Masking does give bidders more latitude to avoid ties, but this has little value. Ties are potentially important only when there are just two bidders remaining on a license, but tend to be rare in that situation because bids usually alternate then.

The advantages to limiting bids to three digits far outweigh any possible disadvantage. ***We strongly recommend adopting this change.***

LIMIT THE USE OF WITHDRAWALS

In the discussions of the spectrum auction design in 1993-94, bid withdrawals were introduced to permit bidders to back out of a failed aggregation. The DEF auction had 789 withdrawals. Few if any of these withdrawals were related to failed aggregations. Rather, most of the withdrawals appear to have been used as a strategic device, in one of two ways: (1) as a signal of the bidder's willingness to give up one license in exchange for another or (2) as part of a parking strategy to maintain eligibility without bidding seriously.

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In the first category, we are especially concerned with the use of what we call "gift withdrawals." A gift withdrawal is used when two bidders (A and B) are competing in two or more markets, say markets X and Y. Suppose B is the high bidder on Y at $100 and the minimum bid increment is $5. A submits a high bid on X and a high bid on Y of $105 and immediately withdraws from Y. (Under present rules, A can amplify the message by coding the high bid on Y with X's market number, as in $105.xx.) B now knows that A is saying, "I will take X and you can have Y." After the withdrawal, the minimum bid on Y falls back to $100, so B can take over Y without having to increase its bid. This is an important feature of the gift withdrawal — it is a clear and effective way to let your competitor know how licenses should be split up. As a result of the withdrawal, A becomes liable for a penalty of $5, but this actually helps cement the collusive agreement, for if B persists in X, A can punish B in Y at a cost of -$5! By coming back with a bid of $105, B is forced to push Y to $110, at which point A is off the hook for the penalty. Although we do not know how many times the gift withdrawal has been used, it does appear to have been successfully used in at least one important case. In the AB auction, WirelessCo appears to have used a gift withdrawal to offer Tampa and Houston licenses to American Portable Telecommunications in exchange for a San Francisco license.

To eliminate "gift withdrawals," we suggest implementing an *irreversible withdrawal rule,* as follows: "A bidder who withdraws a bid from a market area may not subsequently bid again for that license or any equivalent license covering the same market area. The sole exception is that a bidder can re-bid at the minimum bid level on the license from which it has withdrawn after two or more rounds have passed since its withdrawal provided the FCC has been the high bidder in every intervening round."

According to this rule, a bidder can still withdraw its high bid on any license, but cannot bid in that market again (that is, for the same license or any substitute covering the same territory), except after two or more rounds to replace the FCC as the high bidder. With this rule, if bidder A withdraws from license Y to "offer" it to bidder B, A cannot later bid up the price of license Y in case B fails to reciprocate. In our example, B is free to bid actively for both X and Y after A's withdrawal on Y, without fear that A might retaliate with bids in Y for B's activity in X. Such a rule thus eliminates the threat that underpins the effectiveness of gift withdrawals.

An alternative approach adopted for the 800 MHz SMR auction is to limit the number of rounds in which a bidder can make withdrawals. This alternative is effective against the repeated use of withdrawals as part of a parking strategy and, provided the number of rounds in which a bidder can withdraw is quite small (say, two), it also helps to mitigate the problem of gift withdrawals. However, unlike the irreversible withdrawal rule, this alternative does not eliminate entirely the use of gift withdrawals.

Irreversible withdrawals also limit the use of withdrawals in parking strategies. These may involve bidding where one is not truly interested and then withdrawing, or repeatedly withdrawing, so that two bidders can get eligibility credit for the license without raising the price. Limiting withdrawals to two rounds would be even more effective in restricting these parking strategies.

The downside of irreversible withdrawals is that they are likely to be more difficult to implement in the existing software than the alternative approach of a round limit (although the irreversible withdrawal rule can be optionally enabled in the CRA/MDI auction software). There are two reasons for this. First, the auction system must record for each bidder the markets in which it may no longer bid because of its withdrawals. This is still fairly easy, since it amounts to simply updating the eligibility matrix after each withdrawal. Second, a withdrawal from one license should reduce the bidder's eligibility to bid on that or near perfect substitutes by one. Hence, in the AB auction, a withdrawal in any market would exclude a bidder from bidding in that market. The same would be true in the C auction. In the DEF auction, a withdrawal on D by a large bidder active on D and E would reduce its eligibility to one license (D or E) in that market. If the bidder were only active on one license in the market, then its eligibility would be reduced to zero in that market. Hence, the statement of the rule is quite straightforward in a one-license-per-market auction, but is more complex with multiple licenses per market.

Irreversible withdrawals do allow bidders to back out of any failed aggregation, but in each market they can only back out once. Since there has been little evidence of bidders backing out of a failed aggregation after tens of thousands of bids, we view this as an almost inconsequential constraint.

It is important to allow a bidder to come back on its withdrawal if no one else picks it up. Otherwise, the license may end up with the FCC and the penalty for the withdrawal remains undefined (and potentially quite large). We would allow a bidder to come back only at the minimum bid and only when the auctioneer is the high bidder. That is, if A withdraws a bid for $105 and the minimum bid falls to $100, then A cannot bid higher than $100. Of course, A has to maintain the eligibility to bid even at the $100 level.

We recommend that an irreversible withdrawal rule should be implemented if feasible in the FCC's software. It would be an important improvement in the auction rules and one that is easily explained to the bidders. ***If this implementation is not feasible, we recommend limiting bidders to exercising withdrawals in just two rounds of the auction.***

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ALTERNATIVE CLOSING RULES

The present rule that calls for closing all licenses together when there are no bids on any license was initially proposed to maximize the flexibility allowed to bidders to evaluate substitutes and implement back-up bidding strategies. Any modification of the rule will involve sacrificing some of this flexibility in exchange for some other design goal. For that reason, all proposals for alternative closings are to be applied only once the overall level of bidding activity has become quite low — say less than 2% — when fewer bidders are affected by the loss of flexibility opportunities.

Besides preserving flexibility, two other auction design goals that are important in evaluating proposed closing rules are the two we emphasized in the opening paragraph of this report: limiting opportunities for collusion and speeding the completion of the auction. The present closing rule creates opportunities for colluding bidders to monitor their partner's behavior and to retaliate against violations of a collusive agreement. For example, suppose the arrangement is that bidder 1 will refrain from bidding on license A in exchange for 2 refraining to bid on license B. With the current rules, if bidder 1 ever cheats on the arrangement, 2 will observe the violation and have an opportunity to retaliate at the next round. The rules discussed below limit a colluder's ability to observe and retaliate in this way.

Related to the retaliation theme is the theme of demand reduction. Large bidders in a simultaneous multiple round auction may "accommodate" the license demands of smaller bidders in order to keep overall price levels low. It is the very success of the auction in allowing substitution among licenses that leads to this accommodation effect. The alternative closing rules all mitigate this effect *because* they limit substitution: they allow a large bidder to bid aggressively near the end of an auction without raising the prices for all the other licenses on which it is high bidder. The result would likely be an increase both in the total value of the license assignment and in the share of licenses held by the largest bidders.

Another reason sometimes mentioned for modifying the closing rule is to reduce the time needed to complete the auction. Some observers have suggested that there may be little loss in seeking an early closing of some auctions, because so much of the important work is done early in the auction. In a recent e-mail, Professor Dan Vincent summarized the recent evidence for this view:

"In the 185-round C-Block auction, bidding activity never rose above 2% after round 97. In that round, 98% of the net revenue had been raised, 88% of the licenses had received their final bid, and 95% of the licenses were held by the ultimate winner. In the 275 round D, E, and F Block auctions, bidding activity never rose again above 2% after round 181. In that round, 98% of net

revenue had already been raised, 91% of the licenses had received their final bid and 96% had current high bids from the ultimate winner."

Closing rules are just one of several alternative ways to speed the auction. We consider some others later in this report. This section restricts its focus to an analysis of the closing rules, primarily from the perspective of limiting collusion by limiting the ability to "observe and

Final Sealed Bids

One way to limit a colluder's ability to observe and retaliate that has received some attention is to announce a final "sealed-bid" round once activity has substantially slowed. A bidder who violates the collusive agreement at the final round is protected against retaliation in that auction. While the anti-collusion benefits of a final sealed bid round are real, they are limited by an effective activity rule. Many bidders will simply not have the free eligibility needed to place many new bids in the final round.

The final sealed bid has the additional advantage that it may shorten the auction, since experience shows that the auctions often end with many rounds of relatively low levels of activity.

In our opinion, the use of a fixed final round closing rule has decisive disadvantages that should lead to its rejection.

The first disadvantage is that a bidder who loses at the final round may have been ready to be high bidder on a substitute license. This is particularly important in an auction like the AB auction in which nearly every license had a close substitute, but is also important in the C auction where the substitution possibilities were rich despite the absence of perfect substitutes.

The second is that a fixed final round can greatly magnify the incentive to bid insincerely early in the auction. If we were advising bidders in an auction with such a closing rule, we would consider a strategy of withholding bids on licenses with few interested bidders until late in the auction to keep those licenses among the last to be settled. Then, we could hope to get a good bargain in the final round. We might be inclined to recommend parking strategies to avoid bidding on the licenses of direct interest. A good auction design should avoid creating such incentives.

A third disadvantage is that a fixed final round is likely to favor larger bidders. These bidders have the greatest incentive to bid aggressively in the final round due to strategic demand reduction in earlier rounds, and they have the greatest free eligibility with which to bid. Hence, we may expect that a forced closing will result in a more concentrated assignment of licenses and a thus may conflict with the FCC's preference for diverse ownership.

In reaching our conclusion, we have considered several ways in which the fixed final round rule might be modified to limit its disadvantages. For example, the rule for the final round can include a parameter (say 2%), which is a trigger for both initiating the final round and continuing the auction. Under this rule, when the activity falls below 2% (in stage 3), then the FCC announces that a final round will occur in three rounds provided activity stays below 2%. If activity rises above 2% in the final round, then the auction continues as normal.

This rule variation mitigates somewhat the inefficiencies of the closing. However, it also limits the anti-collusive gain of the forced closing, since bidders who cheat at too large a scale know that their activity extends the auction and creates an opportunity for partners to retaliate. For example, in a BTA-based auction like the C auction, each of the top-5 BTAs has more than 2% of the pops, and together the top-5 BTAs account for 21% of the total. Any two bids in the top-20 (41% of the total) would be greater than 2%. Hence, collusion is really only deterred on the smaller markets. These smaller markets tend to be what is left for the smaller bidders.

A second modification is to limit any bidding in the final round to the top two bidders on each license. This prevents bidders from coming out of nowhere. It would also permit restoring eligibility in the final round to initial levels. This would have the greatest impact on deterring collusion, but it creates many opportunities for gaming by sophisticated bidders.

License-by-License Closings

Another possibility is to have license-by-license bid closings late in the auction, once the level of new bidding activity has fallen to 5% or even 2% for several rounds. At that point, bidding would close on licenses that have been inactive for, say, three rounds. Like the final round rule, license-by-license closings would limit the possibility of substitutions late in the auction, but the limitation is much less severe. In practice, this rule would never limit bidders from substituting among individual licenses that are near perfect substitutes, as the previous rule would. By avoiding the final sealed-bid stage, it would avoid some of the incentive for parking strategies. And, like the final sealed bid, it would help discourage collusion by offering protection against retaliation on the closed licenses.

In practice, this rule would not be nearly so effective as the final round rule in leading to an early close of the auction, since bidding on the last few licenses would still need to play out. However, bidders whose licenses have closed need not be concerned about the last rounds, so this closing rule could still achieve the desirable effect of reducing bidder costs.

If a license-by-license closing is implemented, it should only apply once activity has become very low and the auction system should warn bidders about the set of licenses that will close if there are no new bids. Even if only one-round notice were given, it would be possible for a bidder in the next round to withdraw in one market and rebid in another, using the eligibility freed by the withdrawal. (As described next, a combined withdrawal/submission phase would allow this.)

We conclude that the license-by-license closing rule is the best of the modified closing rules, but that all of the proposed new closing rules create undesirable restrictions on bidder flexibility late in the auction. The license-by-license closing may be particularly harmful in auctions with important complementarities, where some elements of the package may be in play until late in the auction. However, if the FCC soon adopts an alternative auction format involving combination bidding to deal with situations where complementarities are important, a license-by-license closing rule for the remaining auctions could become attractive.

Streamlining the Auction

A second design objective is to streamline the auctions so that they can be run more quickly, with fewer errors and less effort on the part of all parties involved. Many ideas have been advanced to achieve this objective. We evaluate the most important ones below.

COMBINE BID SUBMISSION AND WITHDRAWAL PHASES

We recommend that the bid submission and bid withdrawal phases be combined. Indeed, the original separation of these phases in the FCC rules is an historical artifact of difficulties in programming software for FCC auction #1. The separation was never supported by any explicit analysis and provides little advantage. Its main effect is to impede the pace of the auction.

With a combined procedure, bid submission consists of two steps: withdrawal followed by submission. In the withdrawal step, the bidder may withdraw on any or all licenses on which it is the high bidder. Then, in the bid submission step, the bidder places any desired new bids, with eligibility increased to reflect the withdrawals. Hence, a bidder withdrawing in New York can

then place a bid (in the same round) on Los Angeles, because of the eligibility freed by the New York withdrawal.

If our recommendation to limit withdrawals is adopted, then the use of withdrawals is likely to drop precipitously. That provides an additional argument against devoting time in each round to withdrawals that will usually not occur.

YES/NO BIDDING

One of the main impediments to running large-scale auctions quickly is the amount of information that bidders are expected to process after each round. In principle, there could be jump bids on any of the possibly hundreds or thousands of licenses at auction, and bidders have to be alert and ready to evaluate these outcomes which *could* occur, even if they rarely do occur. All of this takes executive time during the auction, because there are just too many possibilities for bidders to plan ahead for all of them. The requirement that bidders evaluate so much information and then determine and enter their bid amounts creates opportunities for mistakes and hence the need for error-checking and possibly withdrawal periods to allow errors to be undone. Accordingly, it would be valuable to simplify the auction by eliminating some of bidders' discretion about bid amounts, both to simplify information processing and to reduce the chance of significant errors.

One idea for accomplishing this objective is to conduct the simultaneous multiple round auction in what we call a "yes/no" format. One can conduct an ascending bid auction for a single object either by allowing bidders to call out bids or by allowing the auctioneer to ask for bids in a specified amount. Similarly, one can conduct a simultaneous multiple round auction either by having bidders name their own bids or by calling for bids of a specified amount on each license and allowing bidders to check "yes" on the licenses for which they wish to bid.

At first glance, it may appear that the use of simple yes/no auctions would slow the pace of the auction, since jump bids would be eliminated. However, the data clearly indicate that the vast majority of bids are at or near the minimum bid, with most of the exceptions coming in the early rounds of the auction. Consequently, we do not expect that excluding jump bids would add many rounds to the auction. Moreover, the simplicity of the yes/no auction would enable the FCC to conduct more rounds per day, the time needed to complete the auction will likely be reduced. This is especially the case if the FCC adopts some of our other proposed changes to incorporate a kind of jump bidding in the yes/no auction and to set starting bid and minimum increments to manage the pace of the auction.

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It is unlikely that there would be any adverse revenue or efficiency losses due to yes/no bidding. Most markets close with a single increment raise by a single bidder, which would continue to be the case under yes/no bidding. Yes/no bids also eliminate the use of trailing digits to signal interests and punishments and make tacit collusion more difficult. Furthermore, preemptive bids (jump bids) are ruled out. Hence, we would expect reductions in collusion and no loss of revenues.

A disadvantage of yes/no bidding is that ties will occur more often than under the present rules, since they happen whenever two or more bidders check yes. In this setting, the tie-breaking rule becomes more important, although we still expect ties to be uncommon near the end of bidding on each license as the top bidders alternate their bids. The current tie-breaking rule uses the bid's time stamp. This may sometimes create an incentive for bidders to rush bids into the system, increasing the chance of error. If this is perceived to be a problem, then it may make sense to change the tie-breaking rule. Breaking ties at random would eliminate any incentive to submit bids too quickly in a round.

We recommend the adoption of yes/no bidding, particularly for large-scale auctions.

BUMP-BACK BIDS

It is common for a standing high bidder that is bumped (out-bid) on a license to rebid on the license in the next round. This two-round process can be accomplished in a single round (at the bidders' discretion) with bump-back bids, which allow the standing high bidder

— to indicate an instruction to bump back if it is bumped by another bidder. An incentive for using the bump-back bid is that its use guarantees that the standing high bidder will remain on top. Use of the bump-back option potentially doubles the pace on active licenses.

We recommend allowing the use of bump-back bids.

PROXY BIDS

Jump bids were used in the narrowband auctions and in all but the first broadband auction to get prices to reasonable levels quickly. An enhancement to the yes/no design sketched above would permit jump bids to occur in a limited way that would still reduce the bidders' need for additional time for information processing and bid entry. We call the alternative design "proxy bidding" because it resembles the use of proxies in standard English auction, in which the auctioneer is given the right to bid up to a specified price on behalf of the absent client.

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Proxy bids allow each bidder to specify its maximum bid for a round for a particular license, which can be specified in terms of the number of increments. Like bump-back bids, proxy bids are contingent on the bidding of others. For example, if bidder X submits a proxy bid of 10 increments and the next highest proxy bid is 7 increments, then X becomes the high bidder with a bid of 8 increments, just enough to top the highest competing bid. Unlike jump bids, proxy bids involve no risk of leaving money on the table. As a result, proxy bids are more apt to be used — and to be used more aggressively — than jump bids. Proxy bids can accomplish in a single round what would take many rounds of back and forth bidding. Effectively, the auction system is instantly doing the sequence of bidding and rebidding that would be required without proxy bids. Only the effect of a proxy bid is reported to other bidders. In our example, it is only reported that X is the high bidder with an 8-increment increase.

Proxy bids are less effective when license values are highly interdependent. For example, when there are multiple licenses in the same market that are near-perfect substitutes, then a proxy bid may leave money on the table if a near substitute can be had for less. If this is anticipated to be a particular problem, a bidder might be given the option to submit a proxy bid for one (or more) licenses in a group of similar licenses. The auction system would then apply the bid to the cheapest license in the group, performing the arbitrage desired by the bidder.

A further advantage of replacing jump bids with proxy bids is that jump bids are sometimes used as preemptive bids to discourage competition. In this use the large jump is intended to signal to others that competing for the license is hopeless. It is not clear that such strategies have been effective, but it is clear that proxy bids do not permit the same type of strategic signaling.

One concern with proxy bids is that they introduce a need for secrecy within the FCC. The fact that a bidder submits a large proxy bid is private information to the bidder and must remain so. In the current auction system, the FCC faces a short window of secrecy during the submission period. At the end of the round, all information is made public. This short window of secrecy is desirable. Fortunately, proxy bids can be implemented so as to maintain it. The proxy bid need only reside on the client machine. During the submission period when a bid is topped, the auction server queries the client as to whether it is willing to go an increment higher. This process continues until no one is willing to bid higher. The proxy bid is then replaced with the actual bid required to stay on top (an 8-increment increase in the example). Alternatively, the proxy bid can reside on the auction server, but not be displayed. At the end of the round, the 8-increment bid is reported together with the 7-increment bid that forced it. This alternative does not require repeated communication with the client, but does require a higher level of secrecy.

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It is difficult to say whether the benefits of proxy bids are worth the cost of added complexity. They are likely to be used at least as much as jump bids. Jump bids have been important in the early stages of several auctions, especially in highly competitive auctions where it becomes clear that prices will go much higher.

There is little to no efficiency loss from yes/no bidding. Bidders sometimes make "death jumps" when they place there last bid, bidding above the minimum bid in the hopes that others will be unwilling to top their last shot. Yes/no bidding forbids "death jumps", but the efficiency effect of death jumps is negligible. Proxy and bump-back bids somewhat restore this ability to be the high bidder near one's valuation, which is the intent of the death jump.

CONTINUOUS AUCTIONS

A possible alternative way to increase the auction pace is to have continuous bidding periods. Like proxy bids, this allows back and forth bidding within a single round, allowing bidders to increase the pace of bidding if they wish without the risk of jump bids that could leave money on the table. However, continuous bidding involves a more substantial modification of the current FCC rules and introduces many complexities. ***As between the use of continuous auctions or proxy bids with discrete bidding rounds, we recommend the latter as the preferred alternative.***

LIMIT INFORMATION IN LARGE, LOW-VALUE AUCTIONS

With the exception of the first narrowband auction, bidders have had access to full information on all bids. This has the advantage of a completely open auction process in which the bidders can condition their bids on all the information and independently confirm the integrity of the process. However, there are two reasons for limiting bid information in the simultaneous multiple round auction. First, the risk of successful tacit collusion is greater when the bidders have all bid information, since the information provides opportunities for signaling and punishment strategies. As a result, the parties may be able to agree on how to split up the licenses without using price to reduce excess demand. Second, the exchange of all information and the bidders' conditioning on this information requires time. Hence, full information limits the number of rounds of bidding that can occur each day. In large auctions for relatively low-value licenses (such as paging), any efficiency gains from better information may not be worth the delay cost. In such cases, the FCC may be better off reporting only the most essential information: the licenses on which the bidder is the high bidder, and the minimum bids on each license.

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We recommend that the FCC maintain the ability to conduct an "anonymous" auction. Anonymous auctions can be used when the costs of the extra information in the standard auction exceed the benefits. This is most likely to be the case in auctions where the risk of collusion is high and where there are many, relatively low-value licenses for sale.

FASTER ROUNDS

One way that the FCC already uses is to employ shorter rounds late in the auction. The justification for this is that with the low levels of bidding activity that characterize the last rounds, the bidders don't need much time to process new information and decide on their bids. Our understanding is that, in the past, the software itself imposed effective limits on the number of rounds that could be run per day, but that the present software is capable of running 20 or more rounds per day, even in relatively large auctions. Increasing the frequency of rounds will be feasible in some auctions and will reduce the time required to complete the auction.

USE MINIMUM INITIAL BIDS OR RESERVES

Minimum initial bids and reserves can both increase the pace and reduce the potential for collusion. In English auction houses, it is quite common for the auctioneer to ask initially for a substantial fraction of the estimated final price and then to reduce the price it demands until a willing bidder is found. A similar procedure can be applied in the simultaneous multiple round auction.

Auctions like the C block reauction present an especially good opportunity to use non-zero minimum initial bids to jump-start the auction, because there is a good starting point for estimating values. Results from the C auction can be used to get a relative value index. Very roughly, if installment payments are not offered in the C block reauction, license values in the reauction will be reduced by about half. Given the presumption from the defaults that the prices paid in the first C block auction were too high, let's guess that final prices will fall by another third, to about 1/3 of the original C block prices, with some higher and some lower. That provides an estimate of the final prices on which reserves can be based.

Imitating the practice of the English auctioneer, the FCC could set declining reserves for each license. The first-round minimum bid for a license might be set at 40% of the expected price, falling to 30%, 20%, and 10% at rounds two, three, and four, respectively, if there are no previous bids for the license. After round four, licenses that had drawn no previous bids would have a zero minimum bid. In this way, it is still the market (rather than the FCC) that determines

all prices, but bidders have some (weak) incentive to jump in early to avoid using waivers. Bidders under this rule would have some incentive to engage in parking. However, even if the early bids are parking bids, the initial activity helps get the auction moving and works against collusive market division outcomes.

An alternative is to set a fixed reserve — a minimum bid that is fixed regardless of bid activity. Such a minimum is set not to increase the pace of the auction but to increase revenues. A fixed reserve eliminates the most collusive, low price outcomes but runs the risk of leaving licenses unsold. Reserves are especially effective in settings where there are large *ex ante* asymmetries among the bidders. Low-revenue outcomes are most likely in this case, since there is often little incentive for bidders to compete with the likely winner. Auctions with incumbents are a good example. The incumbent often has an important advantage over rivals and this deters competition in the auction. Re-auctions are another example. There the initial auction revealed information about the likely winner, reducing the incentive for others to compete.

BID INCREMENTS

In a business like PCS with high levels of value uncertainty and sharp differences in business plans and market and cost estimates, the efficiency gain to using small increments is minute. A minimum bid increment that is less than the difference between the valuations of the two highest bidders never leads to any loss of efficiency. We have explored two ways to use larger increments to increase the pace of the auction: larger fixed increments and increments that vary across licenses according to the activity on each license.

Uniform Bid Increments

In general, to evaluate the appropriateness of a proposed bid increment, one needs information about the likely variation of valuations among bidders. Even the smallest increments ever considered for the FCC spectrum auctions — say 2% or 1% — would be much too large for an auction of, say, Treasury bills, in which the range of valuations is a tiny fraction of 1%.

Consider the possibility of using a fixed 10% increment for spectrum licenses in each stage of the auction. How much value would be lost? To answer this question, one must first quantify the degree of variation of valuations. For example, suppose the two highest bidders' values are at most 40% likely to be within 10% of one another. (On the basis of our experience, we believe that the 40% estimate is very high, which leads to a conservative estimate.) A straightforward calculation shows that the expected efficiency loss from using 10% bid increments in this case is

at most 1% compared to the value-maximizing assignment.[1] With the same valuation assumption, a 5% bid increment would lead to an expected efficiency loss of at most 0.25%. These losses are negligible from a practical perspective, but the gain to using the 10% increment is not negligible. It cuts by roughly half the expected number of rounds (in any stage) compared to using a 5% increment.

License-Specific Increments

An alternative proposal for increasing the pace of the auction is the use of license-specific bid increments. Intuitively, increments should be higher on more active markets. License-specific increments should be applied in all stages of the auction, rather than limited to stages 2 and 3 as in the DEF auction. Indeed, license-specific increments are likely to have the greatest effect early on, since later in the auction, activity is likely to be just 0 or 1 new bid on most licenses. Also, to reduce the gaming associated with large changes in the increments, increments should not change abruptly in response to changes in bid activity.

The basic idea of license-specific increments is to have a larger increment in response to greater activity. Specifically, we want to avoid situations like that which occurred in the C-block auction when the Salt Lake City license received about fifteen new bids for an extended period and its price was only increasing at the rate of 5% per round. Under the proposed rule, the increment is tied to an activity index, which is a weighted-average of past bidding activity on that license, with more recent rounds getting more weight. At least in stage 1, both the absolute and percentage increments need to be tied to activity. The increments are set between a lower and upper bound based on the activity index. Reasonable bounds are a 5% lower bound and a 15% upper bound.

A specific proposal for an activity index is the following one. The activity index is initially 0. In all later rounds, the activity index for a license is x*(number of new bids) + (1-x)*(prior activity index), where x is the weight given to the current round (½ is a reasonable value for x). The bid increment increases linearly with the activity index, subject to the lower bound L and the upper

[1]The calculation goes like this. Consider an auction for a single item and suppose the bidders bid sincerely, making the smallest eligible bid whenever their valuations justify bidding at all. Then, the auction achieves the first best value except in cases in which the high bidders' values are within 10%. Even then, it leads to a loss only half the time, that is, in the sub-case when the wrong bidder wins. Since the value difference between the two bidders is less than 10%, the average difference in values is likely to be at most about 5%. If the first event (values within 10%) happens with 40% probability (which we believe is a very high estimate for spectrum auctions), the expected value loss from the 10% increment is .40x.5x.05 or about 1.0%. If the probability is less than 40%, the expected loss would be reduced proportionately.

bound U. One possible formula, which has been proposed for the 800 MHz SMR auction, is: Bid increment = min (U, (1+ activity index)*L). The table below gives an example of how bid increments might vary across rounds when the increments are set with a lower bound of 5%, an upper bound of 15%, and a weight of ½ on the current round. The example rounds the calculation of the index to the nearest tenth and the bid increment to the nearest percentage point.

Round	New Bids	Activity Index	Percentage Increment
0		0.0	
1	4	2.0	15
2	3	2.5	15
3	3	2.8	15
4	2	2.4	15
5	2	2.2	15
6	1	1.6	13
7	1	1.3	11
8	1	1.1	11
9	0	0.6	8
10	0	0.3	6
11	1	0.6	8
12	1	0.8	9
13	4	2.4	15
14	4	3.2	15
15	2	2.6	15
16	1	1.8	14
17	0	0.9	10
18	0	0.5	7
19	0	0.2	6
20	1	0.6	8
21	0	0.3	7
22	1	0.7	8
23	0	0.3	7
24	0	0.2	6
25	0	0.1	5

Each of the two alternatives for setting bid increments has its advocates on our team. Those who favor the uniform 10% increment admire its simplicity, argue that the associated efficiency loss it imposes is negligible, and point out that this rule avoids creating strategic opportunities to

manipulate bid increments. Those who favor the formula approach emphasize that it is responsive to real differences among individual licenses, improves efficiency by making a more refined selection of the auction winner near the end of the auction, and creates relatively little strategic incentive to manipulate increments. ***Presuming that the pace of the auction is a serious concern, we recommend the use of a rule that makes increments in the range of 10-15% common until near the end of the auction.***