Audio Engineering Society
Convention Paper

Presented at the 121st Convention
2006 October 5–8 San Francisco, CA, USA

Doing Good by the "Bad Boy": Performing George Antheil's *Ballet mécanique* with Robots

Paul D. Lehrman[1] and Eric Singer[2],

[1] Department of Music, Tufts University, Medford, MA 02155, USA
paul.lehrman@tufts.edu

[2] League of Electronic Musical Urban Robots, Brooklyn, NY USA
apps@ericsinger.com

ABSTRACT

The *Ballet mécanique* by George Antheil was a musical composition far ahead of its time. Written in 1924, it required technology that didn't exist: multiple synchronized player pianos. Not until 1999, with the aid of computers and MIDI, could the piece be performed the way the composer envisioned it. Since then, it has been played over 20 times in North America and Europe. But its most unusual performance was the result of a collaboration between the authors: one, the music technologist who revived the piece and the other, a musical robotics expert. At the request of the National Gallery of Art in Washington, DC, they built a completely automated 27-piece orchestra, which played the piece nearly 100 times, without a serious failure.

1. INTRODUCTION

George Antheil's 1924 *Ballet mécanique* for percussion orchestra, sound effects, and multiple player pianos, a composition which was never heard in its original orchestration until 75 years after its creation, is considered one of the major "lost" works of the early 20th century. The National Gallery of Art presented an opportunity to bring *Ballet mécanique* into the 21st century by inviting the authors to install a completely computer-driven orchestra to perform the piece, as part of a major exhibit on Dadaist art. This paper briefly describes the history of the piece and of its revival at the end of the 20th century, and explores the logistical, mechanical, electronic, acoustic, and computational challenges that the National Gallery installation presented.

2. HISTORY OF THE BALLET MÉCANQIUE

Ballet mécanique was composed in 1924 by George Antheil, a young and highly-regarded American composer and pianist living among the literary and artistic elite of Paris. Antheil's ultra-modernist works caused fistfights in concert halls and riots in the streets from London to Budapestm which at the time were considered marks of great artistic achievement. He was,

as his best-selling 1945 autobiography would be titled, the "Bad Boy of Music."[1]

His most outrageous work, *Ballet mécanique,* called for an orchestra of three xylophones, four bass drums, two pianists, a tam-tam, a set of electric bells, a siren, and three airplane propellors, as well as 16 synchronized player pianos. The music was to accompany a film by the same name, produced by artist Fernand Léger and cinematographer Dudley Murphy.

But the technology to perform the piece, and to link it to the film, actually didn't exist at the time: there was no way to get even two player pianos to start together and stay synchronized. Upon realizing this, Antheil reduced the number of player pianos to one, and added a phalanx of live pianists. This version had a triumphant premiere in Paris in 1926. In 1927, he brought the piece to Carnegie Hall in New York, but there it met with such colossal failure that his reputation as a composer was irreparably shattered. The piece was not heard again for 60 years, long after the composer had died.

3. REVIVING THE BALLET MÉCANIQUE

In 1989, conductor Maurice Peress revived the 1926 version of *Ballet mécanique* and successfully performed it at Carnegie Hall. Subsequently, in the early 1990s, New York music publisher G. Schirmer, who had obtained the rights to Antheil's catalogue, decided to take the next step and publish the piece according to Antheil's original conception of using multiple player pianos. Schirmer enlisted the aid of current author Lehrman to convert the player-piano parts in Antheil's score to a multitrack MIDI file, which could be played from a standard sequencer on MIDI-compatible player pianos. Lehrman also collected and edited digital samples of the sirens, bells, and airplane propellors. The full score, along with the MIDI files and samples on CD-ROM, was published by Schirmer in 2003.[2,3]

Lehrman's realization of the piece was premiered by the University of Massachusetts Lowell Percussion Ensemble in November, 1999, with 16 Yamaha upright *Disklaviers* handling the player-piano parts. In 2000, at the request of Anthology Film Archives, who had recently discovered a heretofore unknown print of the Léger/Murphy film, Lehrman also created an edited version of the score to synchronize with the film (which was quite a bit shorter than the original score). These two versions of *Ballet mécanique*, with and without the film, have to date had over 20 performances in the US, Canada, the UK, and Europe. The film, with a recording made by Lehrman of the score, has been shown at some 115 venues around the world, and was released on DVD in 2005.[4,5]

The revival of the piece is the subject of a documentary film produced by Lehrman, *Bad Boy Made Good*, which was presented at both the 117th (San Francisco) and 119th (New York) conferences of the Audio Engineering Society.

4. DADA AT THE NATIONAL GALLERY OF ART

From February 19 to May 14, 2006, the National Gallery of Art was host to "the most comprehensive museum exhibition of Dada art ever mounted in the United States,"[6] incorporating "painting, sculpture, photography, film, collage, and readymades." Prior to coming to Washington, the exhibit appeared at the *Musée national d'art moderne*, Centre Pompidou, Paris, and after Washington it was shown at the Museum of Modern Art in New York City.

Stephen Ackert, director of the music department at the National Gallery, originated the idea of incorporating *Ballet mécanique,* which drew on many Dadaist ideas in its composition, into the exhibit in Washington. His initial concept was for both an automated installation and a performance of the piece with a live orchestra. Unfortunately, it became apparent that the logistics of doing a live performance would be too complex for the Gallery, and so efforts were concentrated on the installation.

5. CREATING THE INSTALLATION

Ackert and his design team scheduled the *Ballet mécanique* installation to be on view March 12-29. The location was the mezzanine lobby of the East Wing building, one flight above street level, directly outside the gallery hall in which the Dada exhibition was to take place (Figure 1).

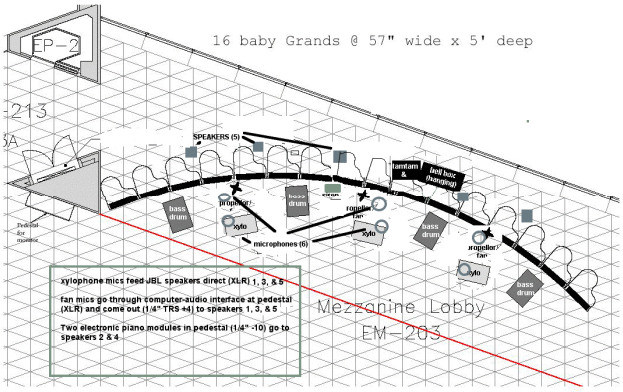

Figure 1— Schematic diagram of the installation. To the right of the pianos an entryway leads into the Dada exhibition hall.

5.1. Pianos

The score for *Ballet mécanique* has four separate player-piano parts, each of which is supposed to be played on four instruments, for a total of 16. However, the piece can be (and has been) played on fewer instruments, as long as the total is a multiple of four.

Yamaha Corporation of America had generously supported the premiere and several other performances of the *Ballet mécanique* by supplying acoustic and electronic *Disklaviers* to the performing groups. Prior to contacting Lehrman, the National Gallery had begun talks with Yamaha, in hopes that the company would support their installation as well, possibly with a reduced number of instruments. Unfortunately these discussions did not result in an agreement.

From his earlier work with other MIDI-controllable player pianos, however, Lehrman knew that instruments using the *Pianomation* system made by QRS Music Technologies could also be used to perform the piece.[2] Upon learning that Yamaha would not be participating, he cold-called Thomas Dolan, president of QRS, to ask whether the company would be interested in lending instruments to the Gallery for the installation. To Lehrman's great surprise, Dolan not only agreed, but he also said he would supply 16 instruments, *and* they would all be grand pianos—the first time *Ballet mécanique* would be performed with such an array of instruments (Figure 2) .

The pianos supplied bore the Gulbransen brand, which is a subsidiary of QRS. The company also sent an instrument to Lehrman's home for for six weeks prior to the exhibition, to allow him to test and modify the sequence file, which had originally been optimized for *Disklaviers*.

Figure 2—End view of the installation with Gulbransen grand player pianos (photo by Charles Amirkhanian)

The two human pianists' parts were played using two Kurzweil *MicroPiano* MIDI-controlled modules, amplified through JBL *EON* powered speakers provided by the Gallery. In addition, in order to blend the tone of the electronic and acoustic pianos as well as possible, Lehrman copied some of the human pianists' parts to the player piano tracks, taking care not to allow the parts to overlap (i.e., doubling notes) on a single instrument.

5.2. Other instruments

The Gallery's original concept was for the percussion and sound effects parts in *Ballet mécanique* to be provided by recordings, or by MIDI synthesizers or samplers, synchronized with the player pianos. But when Lehrman met with Ackert and the Gallery staff in person for the first time in October, 2005, he recalled meeting and seeing the work of current author Singer at the New Interfaces for Musical Expression conference in Vancouver the previous spring,[7] and proposed that those parts be performed on real percussion instruments and mechanical noisemakers, played by MIDI-controlled robots.

Lehrman contacted Singer, who enthusiastically agreed to enlist his group, the League of Electronic Musical Urban Robots (LEMUR) to design and build the robotic players, installing them on percussion instruments that would be rented for the duration of the exhibition.

5.2.1. Percussion

Most of the instrument mechanisms LEMUR constructed for this installation were based on the "BeaterBot" mechanism developed for LEMUR's ModBots.[7] This is a microprocessor-controlled solenoid and lever mechanism used to move a beater at high velocity to strike a drum surface. The mechanism was used more or less directly for the bass drums and tam-tam, and adapted for use with the xylophones and propellors.

For the bass drums, they devised a cross-bar bracket to span one side of each drum. A BeaterBot mechanism was mounted on the bracket and fitted with a steel ball for a striker; steel was chosen because it produced a better attack transient than other materials tested, allowing the drum attacks to stand out better in the mix (Figure 3).

Figure 3—Bass drum with BeaterBot

Similarly for the tam-tam, a bracket arm fitted with a BeaterBot mechanism was mounted to the tam-tam stand, and a steel cylinder wrapped in suede was used as a striker. These materials produced the best combination of transient response and a sustained "blooming" of sound produced by multiple strikes, that is an important part of a tam-tam's timbre.

LEMUR designed and constructed new robotic mechanisms to play the xylophones. They first considered a design using a small number of beaters which could move around to play different keys of each instrument. However, to achieve the playing speeds required by the score, they decided to use a separate beater for each key. This required 44 beaters per instrument (Figures 4 and 5).

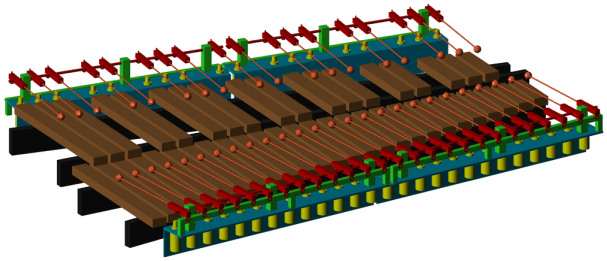

Figure 4—Schematic diagram of XyloBot mechanism

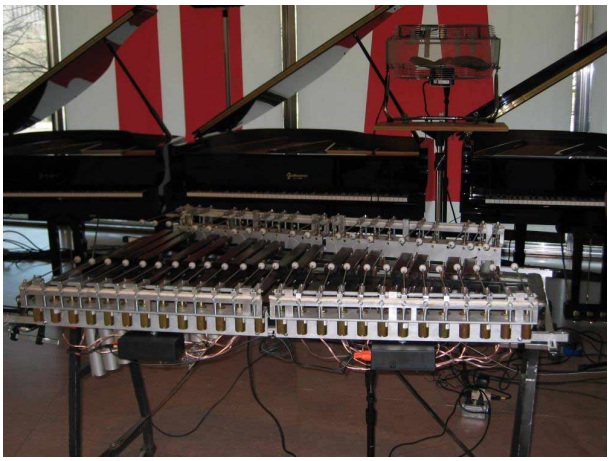

Figure 5—XyloBot mechanisms on a concert xylophone. Propellor mechanism is in the background.

To simplify construction of such a large number of beater mechanisms, beaters were built in sets. Each instrument had four sets of beaters, with two sets of 13 beaters each on the diatonic side and two sets of 9 beaters on the chromatic side.

Each beater within the set had an individual solenoid, pivot mechanism, and beater rod, with the pivot bars in the set mounted on a common shaft. The solenoids pull down on the pivot on the same side as the beater. This is in contrast to the original BeaterBot mechanism, in which the solenoid pulls from the opposite side in a standard lever fashion. This design modification was done for aesthetic reasons, so that the solenoids would hang below the keys, not stick up above.

The beaters are fitted with 3/4" Delrin balls. This was found to produce the best tone out of several materials tested (e.g., other plastics, hard rubber), without damaging the wooden bars.

Each set of beaters is controlled from a custom PIC microcontroller-based circuit which receives MIDI note commands, maps them, and converts them to timed signals to fire the solenoids. Velocity control is effected by controlling the gate time of the solenoids: within a certain set range of gate times, the shortest time will yield the minimum achievable strike velocity and the longest will yield the maximum. This range of gate times is determined experimentally. Firmware parameters are then stored in EEPROM which map note velocities 1-127 to this time range.

5.2.2. Propellors

As they were in Antheil's original performances, simulated propellors were constructed using industrial fans. To create an appropriate sound, a piece of flexible material was inserted into the spinning fan blades—the "baseball card in the bicycle wheel" effect—at specific points in the score. Since the propellor sounds needed to start and stop quite quickly, this was deemed more practical than using a fixed piece of material and turning the fans on and off.

To accomplish this, the team used a push-type solenoid mechanism fitted with a crossbar holding four .04" thick, 1-inch-wide strips of MDS-filled nylon (chosen for flexibility, durability, and sound quality). When energized, the solenoid pushes the bar down, moving the nylon strips into the spinning blades. Again, several materials in various thicknesses were auditioned, with the final choice based on maximum volume of the mechanism and longevity of the strips (Figure 6).

Figure 6—Propellor mechanism installed on 18-inch industrial fan

The propellor parts call for notes to be held for long periods. Therefore, the intermittent-duty solenoid normally used in the mechanism was replaced with a continuous-duty model. A continuous-duty solenoid operates with a lower force (which is not an issue in this case) but may be energized for long periods of time without heat build-up and consequential damage to the solenoid.

Two channels of a Mediamation LM-4 MIDI-controlled light dimmer are used to switch the fans on and off, so they are not spinning continuously through the piece.

5.2.3. Siren

The siren was an electric fire-engine-type wailing siren, running on 117 volts AC and responding in real time to voltage changes by changing its pitch. It was controlled using a third channel on the Mediamation LM-4 MIDI-controlled light dimmer. The unit's ability to vary output voltage according to a MIDI continuous controller input meant that complex siren effects could be programmed into the master sequence.

5.2.4. Bells

The score for *Ballet mécanique* is unclear about how many electric bells are required, but during Lehrman;s initial efforts with with Schirmer to prepare the MIDI files, it was decided to make the number seven. For the Lowell premiere, with the help of engineer Coleman Rogers, Lehrman built a plywood "Bell Box", which is equipped with bells from 2" to 10" in diameter, the largest being an old, obnoxious, red alarm bell from Radio Shack, similar to that found in schools and other public buildings (Figure 7).

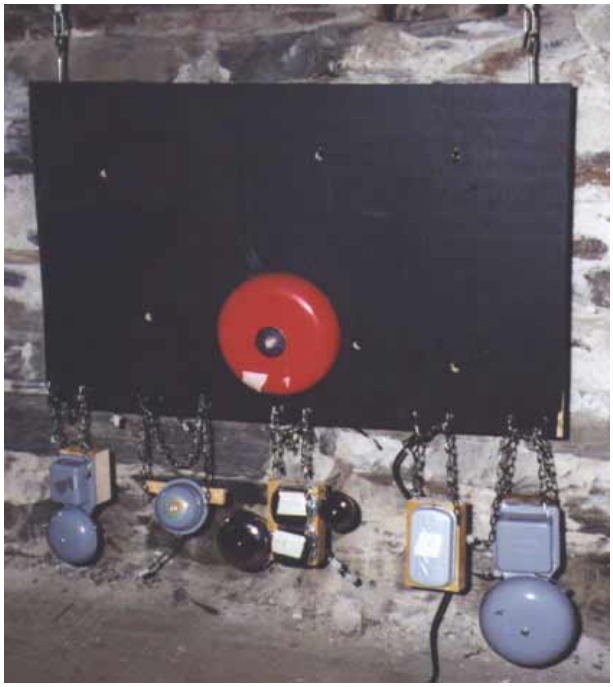

Figure 7—MIDI-controlled Bell Box

Originally Lehrman planned to mount all of the bells on the front surface of the Bell Box, but he found when he did that all of the bells (except the largest, which has its own shock mount) sounded more like buzzers, as the plywood resonated louder than the bell gongs. The solution was to suspend the bells in free air: each bell was attached to a small piece of dense wood, which was in turn hung using short chains from a pair of hooks at the bottom of the Box.

Since the Lowell premiere, the Bell Box has been used for several other performances of *Ballet mécanique*, and there was no question it would be used in the Washington installation. Gallery personnel suspended it from the mezzanine ceiling with aircraft cable. It was noted during the testing phase that the ringing bell mechanisms produced very large transient voltages which were damaging the DC power supplies originally used. Singer rewired the unit, driving the bells with individual AC transfomers to improve the system's reliability.

5.3. MIDI Control and Networking

Ballet mécanique was played by a Macintosh G5 computer running Mark of the Unicorn's *Digital Performer* software. The MIDI streams were generated by a Mark of the Unicorn *MIDI Time Piece USB* with one additional stream from a Mark of the Unicorn *828 Mk II*, which was also serving as an audio interface.

Because of the density of the MIDI data, each group of pianos was assigned a separate MIDI cable, and the signal was daisy-chained through the pianos in each group. (This was not possible with earlier performances using Yamaha *Disklaviers*, because those instruments impose a delay on signals coming out of their MIDI Thru jacks.) The XyloBots all shared a single MIDI output from the *MIDI Time Piece*, with the MIDI signal being distributed via custom MIDI splitters and thru chains. Each XyloBot responded to a different MIDI channel. Similarly, signals were distributed from other outputs to the other MIDI robotics, with each instrument responding to different MIDI notes (Figure 8).

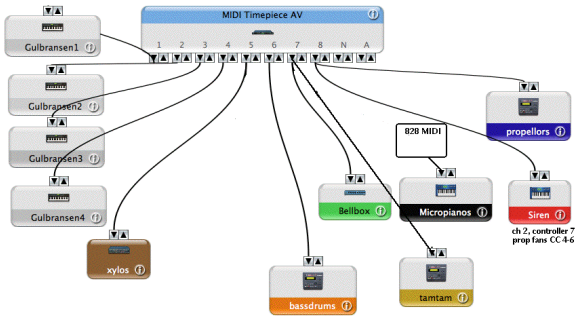

Figure 8—MIDI network (Apple AudioMIDI Setup)

MIDI control of the Bell Box was effected by a MIDI Solutions *R8* MIDI-controlled Relay Array. The low-current relays in the *R8* are not sturdy enough to withstand the heavy currents drawn by the bells, so a secondary tier of relays was necessary.

5.4. Testing and Modifying the Files

A complete performance of *Ballet mécanique* is 25-30 minutes long (depending on the tempo), but the National Gallery requested that each performance there be no more than ten minutes, so as not to scare away too many patrons. As Lehrman had already edited the piece a number of times for several applications (including accompanying the Léger film[4]) with the full cooperation of the publisher and the composer's estate, he was given a free hand to decide where the score would be trimmed.

Before any editing was done, it was necessary to determine how fast the piece was going to be played. Antheil's tempo markings are ambiguous, but the best interpretation says that he intended it to be played at about 150 bpm. This tempo, however, is far beyond the capabilities of any live performers, and the fastest performance to date has been at 120 bpm. Absent the human beings, the limiting factor becomes the mechanical instruments, specifically the player pianos, which have the most complex parts.

In empirical testing when he was preparing the original MIDI sequence[2], Lehrman determined that Yamaha *Disklaviers* could play the piece at 133 bpm, but at any faster tempo repeated notes would start to be skipped. To get the instruments to play even at this tempo, the MIDI data had to be carefully massaged, with certain counterintuitive changes made to velocities and durations in order to get the desired response.

Lehrman's tests on the Gulbransen piano in his house determined that it could play the piece slightly faster—138 bpm—without significant extra customization of the sequences, and so that was the tempo chosen. Note velocities in the sequence were set to a constant value of 80, and an initial Controller 7 (volume) command with a value of 127 was sent on each track. He then edited the score to the requested length, while attempting to preserve all of the thematic and orchestral elements that make it unique. Similar to the *Disklaviers*, the Gulbransen pianos have a built-in delay of 500 ms after receiving a MIDI command, so those tracks needed to be advanced in the sequence by 500 ms.

One major difference between the Gulbransen and Yamaha MIDI player pianos is that the former do not have mechanisms for playing the top and bottom four notes of the instruments' range. According to QRS engineers, these notes are rarely used in standard repertoire, and so those mechanisms are left out as a cost-saving measure. Antheil's score is hardly "standard repertoire," however, and makes great use of those extreme notes, especially the ones at the bottom, for their percussive effect. But although QRS *can* make Pianomation systems that include all 88 notes, they are only available on special order, and the company could not supply 16 such custom instruments to the Gallery. After finding this out, Lehrman modified the sequence files, transposing the eight missing notes up or down as required by four half-steps. Since the piece is so utterly atonal, the change was hardly noticeable.

After editing the sequence, Lehrman sent it to Singer, who tested the appropriate tracks on his robotic instruments. He found that the solenoid instruments responded the best within a small range of velocity values, and although each instrument had its own optimum range, the best velocity for fast, repeated strokes was consistently 30% lower than for individual strokes. The tracks were modified to accomodate this. He also determined that the latencies in his instruments were insignificant and so no track offsets were required.

5.5. Amplification

Only after the installation began to be assembled on site did it became apparent that the airplane propellors and xylophones could not compete in terms of volume with the 16 grand pianos—especially with their lids fully open, which is how the Gallery preferred to set them up. The Gallery was able to supply amplification, in the form of Shure SM57 microphones and additional JBL *EON* powered speakers, for these instruments. We were able to take advantage of the built-in mixing capabilities of the EONs, keeping the total number of speakers (which also handled the Kurzweil *Micropiano* modules as stated earlier) down to five.

One new problem was that the noise from the fans when they were spinning was now being amplified even when they were not making the propellor sounds. Since the fans (which were controlled by the MediaMation LM-4) required a spin-up time of at least five seconds before each cue, amplifying their sound prematurely would significantly lessen their dramatic effect. This problem was solved using the Mark of the Unicorn *828 Mark II* audio interface and a Shure mic preamp. The signals from the microphones carrying the propellor sounds were sent to the *828*'s inputs, which in turn were routed into audio channels within *Digital Performer*. Those channels were record-enabled with "full-time" monitoring, thus allowing the software to control the signal level as it passed through the *828*. Three audio tracks were added to the sequence which contained nothing but fader moves, timed precisely to the start and end of each of the propellor cues. The signals from these tracks were sent to three outputs on the *828*, and from there to the JBL speakers.

5.6. Logistics

The logistics involved in moving, setting up, wiring, testing, and tuning 16 grand pianos, as well as 13 robotic instruments, were formidable, and the time

frame under which the authors had to operate was very tight. Four days before the exhibit's official opening, in the late evening after an unrelated Gallery reception being held in the mezzanine space had finished, two 18-wheelers containing 16 brand-new Gulbransen pianos pulled up to the Gallery doors. A crew of five QRS employees unpacked, rolled in, set up, wired, tested, and tuned all 16 instruments in the space of 12 hours. We then had two and a half days to assemble, cable, mic, and test the rest of the instruments. Fortunately, the staff of the Gallery is used to this sort of thing—they assemble and dismantle huge exhibitions as a matter of course—and they were a great help. The Gallery's electrician, Rob Johnson, for example, put in a dedicated 200-amp circuit and breaker box expressly for the display.

An unannounced "preview" performance of the installation for the sake of the press took place on March 11, and went off without a hitch. The authors had only a few minor tweaks to do before the official premiere the following day.

6. RUNNING THE INSTALLATION

Although the installation was only scheduled to be in place for 17 days, after it had been up for a week the Gallery, thanks to reviews in the Washington *Post*[8], by the Associated Press[9], and on NPR's "Fresh Air"[10], as well as enthusiastic and growing audience response, agreed to extend the run until May 7, almost to the end of the Dada exhibition.

The authors had endeavored to make the installation as foolproof as possible, since neither one of them wanted to have to travel to Washington to fix anything during the run. The only anticipated maintenance issue was the nylon strips in the propellor mechanisms: they would wear away fairly quickly and have to be replaced every couple of days. Singer made sure that the replacement operation was a simple one, and instructed Gallery personnel how to do it, and also left plenty of spare material.

There were only two unexpected problems:

- One of the bass drum beaters would quit about halfway through the piece, when it was called on to play very fast passages. Working with a Gallery technician on the phone, Singer determined that the velocities of the notes it was playing were too high, thereby not giving it enough time to recover. Lehrman created a new version of the sequence file with those note velocities reduced by 10, and emailed it to the Gallery, who replaced the original sequence with the new one.

- The player mechanism in one of the Gulbransen pianos failed sometime during the second week. This could not be diagnosed by phone, so a technician from QRS came in. It turned out the MIDI and control modules on the instrument needed replacing.

7. RECORDING

Such a massive and unique undertaking deserved to be preserved for posterity, and so Lehrman arranged for a multicamera/multitrack taping session the week after the installation opened.

A local businessman who was one of the major private financial supporters of the Dada exhibit, and also produces a program on the arts for a cable-access TV network, volunteered his services and those of his two-person camera crew. Along with Gallery videographer Karl Parker (who had already shot footage of the authors setting up the installation, as well as the premiere and several other public performances), audio director John Conway, and Lehrman, they came to the Gallery one evening immediately after closing. The installation was then run three times, and at each run the cameras (three miniDV and on DVCAM) were placed at a different distance from the installation. Since the synchronization between takes was essentially perfect, we thus ended up with 12 full-length takes.

For the audio we obtained a Soundfield Mark V Ambisonic B-format surround microphone system, which was loaned to us by Soundfield's American distributor, TransAudio. It did an excellent job of capturing the voluminous Gallery interior, whose reverb time we informally measured at six seconds. The system produces four B-format signals and a stereo output pair, and we recorded all six outputs.

In addition, John Conway contributed several mics to the session: a Neumann USM 69 stereo mic, set to an X–Y pattern, placed right in front of the ensemble; and a pair of Schoeps CMC 5Us, with MK-1 capsules set to omnidirectional, at the left and right ends. These mics were fed through a Millennia Media four-channel preamp.

The audio was recorded using *Digital Performer* and Mark of the Unicorn *828* and M-Audio *Firewire Solo* interfaces, at 48 kHz/24-bit. The video was transferred to hard disk and edited by Lehrman in *Final Cut Pro*. It was presented publicly for the first time by Singer at the New Interfaces for Musical Expression conference in Paris in June, 2006. The stereo mix was done in Lehrman's studio. The surround mix, which is being heard for the first time at this conference of the Audio Engineering Society, was done by Jonathan Wyner at M-Works Mastering, Cambridge, Massachusetts.

8. CONCLUSIONS

The *Ballet mécanique* installation at the National Gallery of Art proved to be one of the most popular exhibits in that institution's history. Thousands of listeners gathered for the twice-daily performances, which the *Washington Post* called "the best ten minutes of free fun in Washington."[8].

We were delighted to have been asked to participate in this monumental artistic and technical undertaking. We believe that the spirit of the installation was faithful to the composer's intentions, extrapolating them using present-day technology in a way he would have been most approving of. Charles Amirkhanian, executor of the Antheil estate, flew in from San Francisco just to hear the opening-day performance, and pronounced it "Perfect!" In addition, we were pleased to be able to bring this unsung composer's music to thousands of people who would otherwise have never experienced his unique vision.

9. ACKNOWLEDGMENTS

The authors wish to acknowledge the invaluable assistance of Stephen Ackert and the audio-visual, design, and electrical staff of the National Gallery of Art; Tom Dolan and the employees of QRS Music Technologies; the members of LEMUR; Jim Cooper of Mark of the Unicorn; MIDI Solutions, Inc.; Tom Klarner, William Holab, Charles Amirkhanian, Julian Pellicano, John Strawn, Howard Sherman, and Ron Frank.

10. REFERENCES

[1] Antheil, G. *Bad Boy of Music*, Garden City, NY, Doubleday, 1945.

[2] Lehrman, P., "The Revival of George Antheil's 1924 *Ballet mécanique*," unpublished Master's thesis, Cambridge, MA, Lesley University, 2000.

[3] Antheil, G., *Ballet mécanique*, New York, G. Schirmer, 2003.

[4] Lehrman, P., "Moving Pictures," *SoundOnSound* magazine, Cambridge, UK, September 2002

[5] *Unseen Cinema: Early American Avant-Garde Film 1894-1941* (DVD), Chatsworth, CA, Image Entertainment, 2005.

[6] "First Major International Dada Museum Exhibition in the United States Opens at the National Gallery of Art February 19-May 14, 2006," http://www.nga.gov/press/exh/202/index.shtm

[7] Singer, E., "A Large-Scale Networked Robotic Musical Instrument Installation," Vancouver, BC, Proceedings of the conference on New Interfaces For Musical Expression, 2005.

[8] Kennicott, P., " 'Ballet Mecanique': Dada's Siren Song—A Bravura Staging of George Antheil's Classic Brims With Mirth and Meaning," Washington, DC, *Washington Post*, March 20, 2006, Page C1

[9] Hartman, C., "Robotic Instruments Play in D.C. Gallery, *USA Today*, March 12, 2006

[10] Schwartz, L., "Dada at the National Gallery," April 4, 2006, http://www.npr.org/templates/story/story.php?storyId=5323011