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THE MAKING OF ANDRÉ & WALLY B.
***** DRAFT August 14, 1984 *****

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INITIAL CONCEPTS

Upon returning from SIGGRAPH 83‡ in Detroit, Ed Catmull and I decided we would push for a big show at SIGGRAPH 84. This would include publishing many of the results developed by the Graphics Department personnel since its inception and finishing the prototype Pixar compositing station hardware and displaying it. We would also make a short demonstration of 3-D character animation to show at the SIGGRAPH 84 film show.

The production group was to consist of Bill Reeves and Tom Duff for modeling and animation and Rob Cook and Loren Carpenter for rendering. The purpose of the piece was to center our software and algorithm development efforts on a definite goal. Bill and Tom had already developed the rudiments of a modeling/animation system as part of their contribution of a 3-D "holographic" display device to *Return of the Jedi.* Rob and Loren were to implement their new rendering algorithms in software to simulate future hardware developments (the Pixar 3D) anyway. This project seemed to be a natural extension of efforts already underway. Furthermore it provided a chance to do a small piece of production which members of the Graphics Department (formerly the Graphics Project) tend to find stimulating. The piece was to be strictly an in-house production for demonstration purposes.

My original proposal to the group for the piece was very simple. An android would wake up in a woods, get up, turn around, see a beautiful scene, and be happy at seeing it. The goal as stated in the meeting notes of July 31, 1983, was "to render a showable sequence of 3-D articulated animation, with edits, in a rich setting. Motion blur very desirable, texture/bump mapping mandatory." The piece was meant to be symbolic: A computer-animated 3-D character wakes up and sees the world.

The original storyboard consists of nine crude thumbnail sketches with the following captions:

1. Dark forms.
2. Sunlight breaks through in shafts. Establish that light is breaking through in several places.
3. X-diss (cross-dissolve) to highlit area which is forest-like but moves occasionally.
4. Android, camouflaged, sits up. Hard to distinguish him from forest.
5. CU (closeup) from below. Yawn. Stretch. Camouflage begins to melt in face.
6. Medium shot to watch arising android. Less and less camouflage; more and more skin.

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‡ SIGGRAPH is the Special Interest Group on Computer Graphics of the Association for Computing Machinery (ACM). It holds an annual conference; SIGGRAPH 83 is the conference held in 1983. Approximately 20,000 people attend each of these conferences. Each conference has technical paper presentations, tutorials, an art show, a film/video show, and an equipment show. SIGGRAPH 84 was held July 25-27 in Minneapolis.

7. He arises. More sun. Less and less camouflage; more and more skin. He smiles and reaches out.
8. Cut to CU of smile. Full day attire. Sunrise and mountains reflected in face.
9. Cut to glorious back view long shot. Pull away a bit during shot.

The motivations were several. First, we wished to show *articulated* animation as opposed to rigid-body animation so popular with most computer graphics houses. Second, we wanted a *character*. This was the reason for the android stipulation. My first drawings of him were nothing more than a stick figure with long skinny ellipsoids instead of sticks, but he had definite arms, legs, torso, and head. Third, I wanted to show filmmakers, particularly within Lucasfilm, that our group knew about editing and other cinematic techniques.

The forest set was motivated by talks earlier in the year with a group from Walt Disney Productions. The group was considering producing an animated piece to be called *The Brave Little Toaster* and wanted to know if we could produce a computer-generated 3-D forest set through which conventionally animated characters would move. One member of this group whom I quite liked was John Lasseter. As will be seen, John figures prominently in the remainder of this story. At the time, however, I quickly volunteered that we could do an elaborate forest set, a belief based on my predilection for rendering plants and trees. So, having already convinced myself that we could do a forest, it was natural that a forest set was what I first thought of for the new piece.

I had referred to the android as "André" in early presentations of the storyboard, and the name stuck. We stumbled over several names for the piece-to-be such as *Androids Awake* before settling on a joke name, *My Breakfast with André,* in honor of a film many of us admired, as our internal name. Perhaps the most interesting parts of this story are how the initial concepts outlined above transformed into the finished piece, *The Adventures of André & Wally B.*

INTERESTING TWISTS

Two important events occurred during the early stages of the production. I count these as two of my best moves as director and don't want to imagine what the piece would have been without them.

First, I suggested to Bill Reeves that he might apply the particle systems he used so successfully for fires in the Genesis Demo of *Star Trek II: The Wrath of Khan* to make trees. This took a little ego-eating on my part because up until that time I had been the only member of the group who had made pictures of plants. There is an unwritten "law" that forbids any of us from stepping into territory already claimed by other members of the group. The strength of our group depends on such respect for the other members and their sensitivities. Now I'm sure Bill had already thought about making particle system trees but he needed an okay from me to do so. Whether he did or not, I gave it to him. I did not have time to build forests in addition to my other responsibilites, and he needed something to turn his considerable creativity to. The success of the final forest sets attests to the "wisdom" of this early decision.

Second, I heard that John Lasseter was between jobs at Disney and urged Ed Catmull to hire him as a consultant. Ed and I had visited John at Disney since his original visit to Lucasfilm. He had shown us through the Disney archives, a tremendous treat to both of us. He continued to impress me with his willingness to consider using the computer in animation. He had already helped in a test with MAGI of Elmsford, New York, which used a computer generated camera move in a 3-D background as a guide to conventional animators for creating the foreground action. He was one of the handful of conventional animators we had met over the years who seemed to see the same promise of computer-mediated animation that we saw.

In November 1983, Ed called me from the Queen Mary in Long Beach where he was giving a talk. During the course of our conversation, he mentioned that he had run into John at the meeting and that John was between jobs at Disney. He had finished the MAGI test and was waiting for further developments on *Toaster*. Without hesitation, I quickly and strongly urged Ed to find John and offer him a consultant's position with the Graphics Department immediately.

Luckily, I had put just such a slot in my most recent budget. Ed did it, and John joined us for what was to be a fine collaboration. He was officially a consultant hired to advise us on our 3-D animation program interface, which we realized would suffer without such professional input.

A third event which was to have a major impact on the project was the involvement of Cray Research Inc. in it. It had been clear to Ed and me for some time that we were greatly lacking in graphics computation power. We had begun a search - still underway - for cost-effective computers to replace our reliable but very slow VAX's. The so-called supercomputers, those of Cray Research and Control Data Corporation, were immediate candidates. This fit in exactly with the desires of Bence Gerber, our local Cray sales representative, who was looking for placement of a Cray in a commercial environment. We were to use our rendering software in the production of *André & Wally B.* as a serious benchmark of real code running on a Cray. The piece would have been impossible without this involvement.

As it turned out, we used five VAX's at Lucasfilm, ten VAX's at Project Athena at the Massachusetts Institute of Technology, and two Cray's at Cray Research in Mendota Heights, Minnesota, for the 1.8-minute piece. The Cray machines used were a two-processor Cray XMP-2 and a four-processor Cray XMP-4, the most powerful machine in the world at the time (four cpus working in parallel), and just announced.

NAILING IT DOWN

The production now began to take definite shape. Bill began a search for effective ways to generate complex trees. I brought in all my tree books for inspiration as well as pages torn from my home state's magazine *New Mexico Magazine*. John brought a stack of *Arizona Highways* magazines from the Disney reference collection for further ideas. Before long, the Graphics Room monitors were displaying very nice evergreen trees which Bill modeled after red spruces.

One of the original ideas was that of a camouflage texture on André which disappeared with the increasing light at sunrise - a substitution of day texture for night texture. This required a leaf-strewn forest floor into which André could be camouflaged. We chose aspens as our deciduous species. This should not be surprising considering the magazines we were using for inspiration.

Bill designed a special rendering system to make his trees. It was based on the line-drawing software of Tom Porter. He added subtle coloring schemes to his program's capabilities so that it could handle non-real lighting schemes. One of John's first suggestions was that we use a Maxfield Parrish lighting model. The production staff had trooped down to San Francisco to see an exhibit of Parrish's works to understand his colorful backlighting. Rob Cook helped Bill design a method for simulating the internal shadowing so important to effective plant rendering and also a method for mutual shadowing of the trees.

Tom Duff was very inspired by the presence of a professional animator who would use his 3-D animation system. He immediately added many of the features John requested after his first few tries at the new system. For example, computer scientists always number from 0 but animators always number from 1. So Tom changed his 0-origin displays to 1-origin displays.

When I showed John the crude storyboard described above, I encouraged him to use it only as a guideline. In particular, the stick figure André could look entirely different so long as he remained an android. I told him that, although we would eventually be able to model complex plastic shapes, it would be far easier for us if he would try to stick to modeling from simple primitives such as ellipsoids and cylinders. I also showed him a little figure I had always admired and hoped to be able to computer generate someday. It is an airbrush picture by Charles White III called "Running Chrome Man" which I saw in a book called *Air Powered: The Art of the Airbrush* produced by Richard Childers for Random House, New York, 1979. The picture is an apparently 3-D cartoon man made entirely of chrome.

John took this input back to Los Angeles for a few days; he was working only occasionally with us at first while he finished up a few projects. He sent me some sketches of his first ideas for André in many different poses. He had carefully adhered to the restrictions we had imposed. The

first response of most of us to his designs was one of mild surprise at the cartoon-like quality of the figures. But I reminded the group that we had given John great design freedom and he had designed in the Disney tradition with which he was very familiar. In fact, one of the things we wanted to stress to people was that the new medium of computer imagery carried the "look" of the artist using it, not that of the computer. John must have sensed that we would respond this way because he asked rather tentatively whether the cartoon-like influence was okay. I assured him it was, though a surprise to us. It shouldn't have been a surprise to me, considering the running chrome man. By the end of the project, everyone had forgotten they ever questioned John's designs.

I took John's sketches of André and began realizing them as a computer model. This was done by writing a description of the model in a language designed by Bill Reeves and Tom Duff called, appropiately enough, **model.** The language is very powerful and extensible. In other words, all the usual primitive forms - spheres, ellipsoids, cylinders, points, lines, patches, polygons, cones, etc. - used by computer graphicists are available in the language, plus it can be extended to handle new forms invented as we go along. André's model required two such extensions, so the extensibility capability turned out to be of basic importance. The final model required 26 pages in this language. It resembles a program written in a C-like programming language and requires the same kind of care.

One of the first attempts at the model used a sphere capped by a cone to realize André's torso. The cone was articulated about the sphere to model bending at the waist but John felt this was just too sterile. All his early thumbnail sketches of the character had a more plastic shape, in the expressive style inherited from Disney's Fred Moore. Ed Catmull claimed he could make a new primitive shape which would fill the bill, and he proceeded to invent it. It is a shape called "teardrop" which allows a fluid bend between its top and bottom rounded forms. This shape was added to the **model** language and got used in a variety of ways in the final piece.

Other shapes which we just could not successfully model with the original primitive forms were André's eyelids and mouth. David Salesin, aided by Ed Catmull and Loren Carpenter, invented a new form to solve this problem and it was added to the model language and to André's model. This was called the "bound" and consisted of a spline-bounded area on the surface of a sphere. These two extensions were key to John's ability to give André convincing character.

John drew up a complete storyboard which helped us tighten up the story. His storyboard panels decorated the walls of the Graphics Room for the duration of the production. He suggested a second character to interact with André, a large bee with a nasty streak in him and a sharp stinger. Homage to the same movie as before dictated that his name be Wally. A production crew brainstorming session modified this into Wally B. The working title changed to "André & Wally B.".

John's design for Wally included four teardrops as "feet" to be animated as if they were water balloons. His animation skill was very apparent when he managed to pull this off, using the computer, of course. Two visitors who were quite impressed by this feat were animation masters Frank Thomas and Ollie Johnston, two of the great "nine old men" who made Disney famous (see *Disney Animation: The Illusion of Life* by these two gentlemen for Abbeville Press, New York, 1981.) The basic animation laws of squash and stretch, anticipation, overlap, and follow through *(ibid,* p. 47) were all demonstrated by this piece of animation. Most importantly to us, they saw a convincing demonstration that none of this was alien to computer animation.

By animating early versions of the André and Wally models, John got used to Tom Duff's animation program **md** (for "motion doctor"). He not only suggested many improvements to the program during this period but also to the models. Animation controls were added to the model as John needed them - another form of extensibility which proved to be very important. The final form of the André model had 547 animation controls, and the final form of the Wally model, by Bill Reeves, had about 252 controls. One of the successes of the animation program was a presentation of this large number of controls to John in such a logical way that he was unaware of the complexity.

John created a set of pastels for background and color inspiration. He and Bill Reeves began one of the most productive collaborations of the piece at this time, sharing thoughts on colors, lighting, tree and rock placement, and the long trucking shot through the forest as the opening. This was to be the one animation of the camera through the background in the film to clue the audience into its 3-dimensionality. All other depth information was carried by the foreground characters in order to save computation time.

Bill used John's pastels as guides for the elaborate background sets featured in the final piece. They are all 3-D even though the camera does not animate through any of them except in the first shot. The pastels themselves ended up in the final piece as background cards for the credits. They were filmed as slides which were then scanned into the computer by laser team members Tom Noggle and Don Conway using the new laser scanner just completed under the direction of David DiFrancesco.

Meanwhile, Rob Cook and Loren Carpenter were perfecting the rendering software which would be used to turn the animated models into finished, fully colored and textured elements to be composited into each frame.in front of Bill's backgrounds. Sam Leffler wrote special purpose texture storage and retrieval programs. Two papers had been presented at SIGGRAPH 83 on motion blur which did not fully solve the problem so Rob and Loren set out to make a complete solution. Without motion blur, animated characters and sets tend to "strobe". This means that each image doubles up - a distracting departure from real-world motion. The solution is to blur every part of an object in the direction of its motion as if it were moving with the camera shutter open. In conventional animation, this is impossible so animators have invented some techniques to approximate motion blur. A familiar trick is the addition of "speed lines" to indicate the blur of a fast-moving character. Another is to show several positions of a character along its path of motion, only the last of which is fully rendered - like a multiple exposure. Sometimes these two tricks are combined. In computer graphics, the problem can be completely solved although no one had done so until Rob and Loren, aided by Tom Porter, turned their attention to it. What makes the problem hard is the fact that objects become visible and invisible *during* a motion - a 4-D problem.

Ed Catmull also made an attempt at this problem. This created a situation of friendly competition in the group which resulted in both teams producing a better result than they would have without the rivalry. It turned out that Ed solved the problem too, but the group felt that the solution by Cook, Porter, and Carpenter (a paper of the proletariat!) was of more general applicability than Ed's. Nevertheless, both groups published their solutions at SIGGRAPH 84. These were two of seven papers by the Graphics Department published at SIGGRAPH 84, 23% of the papers this year.

Rob and Loren implemented their solution in a program called **reyes** (for Renders Everything You've Ever Seen), with Rob principally responsible. Thus André and Wally are always motion blurred in the film. Rob included in the program his new technique for specifying and controlling texturing and shading, called "shade trees", the subject of another of the Lucasfilm papers at SIGGRAPH 84. **Reyes** is our principal rendering system, consisting of about 45,000 lines of code in the programming language C. One of the main purposes of *André & Wally B.* was to test the algorithms realized in this program, some of which will eventually be committed to hardware in the Pixar 3D picture computer.

THE MIDDLE MONTHS

While Bill was developing his tree and grass program **mktree,** John was animating several shots, and Rob and Loren were implementing **reyes,** several changes occurred in our internal makeup. Tom Duff, who had been with some of us for eight years, decided to leave and join Bell Labs. Being the sensitive person that he is, Tom did not make his move until his animation program **md** was fully functional and solid. It was the animation workhorse for *André & Wally B.* Fortunately, Eben Ostby wanted to move over from the Computer Division Systems Group to the Graphics Department. We brought him over and he immediately made some additions to the animation program. These had been requested by John Lasseter, as usual, to ease the animation

task.

Another person, Craig Good, moved into the Graphics Department at this time. Craig had been helping us a great deal anyway in the seemingly infinite logistics problems, so we just made him official. He took charge of all logistics: backups, filming, optical house negotiations, camera rental, tape and disk management, etc. This is one of the most important parts of any animation, particularly computer animation, but it tends to be unsung. Eben and Craig immediately became strong members of the production team.

I heard that Tom Duff was attracted to Bell Labs by the possibility of working on a Cray supercomputer. He did not know that we would soon be involved with Cray in a substantial way. None of us did at the time he left.

Since we will be needing substantial computing power both before and after Pixar 3D comes into existence, we began arranging to run benchmarks on some of the larger machines as well as on the VAX computers we have at Lucasfilm. One of the prime candidates for increasing our computational capabilities is, of course, the Cray supercomputer. Cray Research Inc. agreed to let us implement **reyes** on their in-house machines as a serious benchmark of our production software. This began a generous contribution of computer time and software assistance by Cray Research. Rob, Loren, and Eben were to spend many, many hours at the Mendota Heights facility running this test. Steve Perrenod, a Cray software analyst, in particular, gave us much help in adapting our software to the Cray machines. John Alldag, Janet Low, and Tom MacDonald made life easier for the group who spent many sleepless nights in Mendota Heights; the most readily available slots on the big machines were at night in the wee hours.

THE BIG PUSH

As SIGGRAPH 84 neared, and since we had chosen this as our deadline, the effort to finish *André & Wally B.* intensified. Bill began using all five VAX computers at Lucasfilm. Three of these are used by other groups during the work day, so Bill made sure that they were computing backgrounds for the piece during the night. He also arranged with a friend of his to use idle time on the ten VAX 11/750s which form the Project Athena network at MIT. These were all employed to compute the opening trucking shot across Bill's forest of 46,254 trees, all different. Bill invested immense amounts of time in the effort of mananging all these disparate computing resources while continuing to develop the details of the individual backgrounds. Eben Ostby implemented a hidden surface solver for this shot and the backgrounds.

Rob and Loren began spending more and more time at Cray in Mendota Heights, mastering a different operating system environment and helping Cray to debug its new C compiler. Later Eben joined the Mendota brigade. These fellows were to demonstrate superhuman powers of endurance in the final race against the clock. During the final week of computations before SIGGRAPH 84, Rob got four hours of sleep in a week and Loren got six! They literally hand scheduled the four processors of the Cray XMP-4 and the two processors of the Cray XMP-2 to keep all six cpus operating at close to 100% capacity. They not only generated nearly all the André and Wally elements but also composited them against Bill's backgrounds at Cray.

A sound track was clearly needed to bring the piece together. I had approached several members of the Digital Audio Project asking for help, but they were gunning for their own deadline on the digital mixers for Lucasfilm's Skywalker Ranch and could not help. As sort of an afterthought - never believing he would even hesitate before saying No - I approached Ben Burtt whose studio is in our building at Lucasfilm. Ben is the Academy Award winning sound designer for such films as *Star Wars* and its sequels and *Raiders of the Lost Ark* and its sequel. Much to my surprise and delight, he said he had nothing creative to do for a week or so and besides he was rather intrigued by the weird project upstairs anyway. Arrangements with Jim Kessler, manager of Sprocket Systems, our post-production division, went smoothly and Ben did our sound track! This was the last of the surprising twists to which I attribute the success of *André & Wally B.*

John, Craig, and I shot pencil tests of the piece and edited them into a locked print for Ben's audio effort. We used a program for rendering pencil tests by Steven Baraniuk, an MIT

student working with us for the summer. Visits to Ben's studio found him blowing through stretched rubber bands and swinging toy jets around his head to find a sound for Wally. He eventually used a cousin of the Bronx cheer mixed with a "thhip - thhip - thhip" sound (a tribute to *Apocalypse Now* he says) for Wally made with his own tongue. Other sound sources used were a ricocheting bullet recorded in Utah, a thump on a balloon, and reverberations of a sheet of plastic. These were combined with cartoony music from a sound library in San Francisco for the final track. Parts of the track were processed with the ASP (Audio Signal Processor) by our Digital Audio Department.

Ben had some discomfort with the "story" as we first presented it to him. This inspired John to change it slightly for a cleaner ending. This suited me fine since it required less animation and less rendering, both of which we had no time for. Furthermore it was a better story.

Craig made all the arrangements for camera rental from Alan Gordon Enterprises in North Hollywood and with Monaco Labs in San Francisco for negative cutting and prints. Monaco agreed to work overtime so that we could compute every last minute before show time in Minneapolis at the Electronic Theatre of SIGGRAPH 84. As it turned out, I got the answer print from him the morning it was to show in Minneapolis and did not see it until it went on the screen that night.

Craig, Bill, John, and I were also not sleeping during the last week, but I don't believe any of us matched Rob's or Loren's effort. Another person who unexpectedly joined in for the final push was John Seamons, from the Systems Group, who cracked a magtape from Cray when several others had failed to do so. John's effort was greatly appreciated; it saved us many hours, every one of which counted at this point. Another who helped in the last push was David Vezie who backed up our precious frames onto magtape as they arrived from Cray. We had five disk crashes during the last two weeks - after having none for over a year - so such precautions were mandatory.

SIGGRAPH 84

Much to our surprise, George Lucas announced almost at the last minute that he was going to the SIGGRAPH 84 the night of the Electronic Theatre. When Cray Research heard this, they gave us one final day's worth of computing which we didn't expect. But even with this fine gesture, we were not quite able to finish all the necessary computations. We decided that it should be shown anyway, since it was so near completion. Because Bill had completed all the backgrounds, we decided to put pencil-test line drawings over the backgrounds for the two shots (about six seconds) which were incomplete. The sound track was complete and delightful. We believed the SIGGRAPH people would like to see the mechanics of the production. Furthermore, after the valiant efforts expended by the group to show the piece to our colleagues at SIGGRAPH, I could not dare suggest that it not be shown!

The big week arrived. The Lucasfilm Graphics Group made a big showing with seven technical papers, four tutorials, two panels, the presentation of the Pixar 2D, and, of course, *The Adventures of André & Wally B.* We announced just prior to showing it that it would be completed and premiered in three weeks at the International Animation Festival in Toronto. We also announced that it would eventually be laser scanned onto film. George came to our celebration afterwards and offered his congratulations. He was lost in a room full of bright red tee shirts featuring André and Wally. These were designed by John Lassiter as one of his last creative efforts before departing for Los Angeles to co-direct *The Brave Little Toaster.*

FILM CREDITS

Forest design and rendering: William Reeves.

Character design and animation: John Lasseter.

3-D animation program: Tom Duff, Eben Ostby.

3-D rendering: Rob Cook, Loren Carpenter.

Concept/direction: Alvy Ray Smith.

Andre and Wally models: Ed Catmull, Tom Duff, John Lasseter, William Reeves, David Salesin, Alvy Ray Smith.

Laser scanning: David DiFrancesco, Tom Noggle, Don Conway.

Computer logistics: Craig Good.

Sound design: Ben Burtt (Sprocket Systems).

Texturing/compositing software: Steven Baraniuk, Sam Leffler, Tom Porter, John Seamons.

Cray XMP-2 and Cray XMP-4, Cray Research Inc.: Bence Gerber, Steve Perrenod, John Aldag, Janet Low, Tom MacDonald.

10 Digital Equipment Corporation VAX 11/750s: Project Athena, Massachussets Institute of Technology.

SOFTWARE

gt ("Get picture"): Picture retrieval program (from disk) by Thomas Porter.

gtxt, svtxt ("Get Texture, Save Texture"): Texture formating programs by Sam Leffler.

hv ("Horizontal, Vertical"): Filtered size changer by Alvy Ray Smith.

md ("Motion Doctor"): 3-D animation program by Tom Duff, with extensions by Eben Ostby and William Reeves.

me ("Model Editor"): 3-D modeling program by William Reeves.

mg ("Merge"): Compositing program by Thomas Porter.

mi ("Model Instantiator"): Inbetweening program by William Reeves.

mktree ("Make Tree"): Tree, grass, and flower generator by William Reeves.

mp ("Model Previewer"): Animation pencil testing program by Steven Baraniuk and Loren Carpenter.

paint: 2-D painting program by Thomas Porter.

reyes ("Renders Everything You Ever Saw"): 3-D rendering program with motion blur, hidden surface removal, texture mapping, bump mapping, etc., by Rob Cook and Loren Carpenter.

td ("Terrain Dicer"): 3-D database subdivision program by Eben Ostby and William Reeves.

HARDWARE

Adage/Ikonas 32-bit framebuffers and microprocessor.

Evans & Sutherland Picture System II vector display.

Hitachi tablets.

Fujitsu Eagle winchester disk drives.

Control Data Corporation removable disk drives.

Digital Equipment Corporation VAX computers: Three 11/750s and one 11/780 at Lucasfilm, ten 11/750s at Project Athena of MIT.

Cray Research Inc. computers: One Cray XMP-2 and one Cray XMP-4